MECHANICAL MINING IN SOME BITUMINOUS-COAL MINES

PROGRESS REPORT 6. EXTRACTION OF PILLARS WITH MECHANIZED EQUIPMENT

BY WILBUR A. HALEY, JOSEPH J. SHIELDS, ALBERT L. TOENGES,
AND LOUIS A. TURNBULL

* * * * * * * * * Information Circular 7631

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary
BUREAU OF MINES
J. J. Forbes, Director

Work on manuscript completed November 1951. The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is made: "Reprinted from Bureau of Mines Information Circular 7631."

April 1952

MECHANICAL MINING IN SOME BITUMINOUS-COAL MINES

Progress Report 6. Extraction of Pillars with Mechanized Equipment

by

Wilbur A. Haley,[1] Joseph J. Shields,[1] Albert L. Toenges,[2]
and Louis A. Turnbull[3]

CONTENTS

	Page
Introduction	1
Acknowledgments	2
Summary and conclusions	2
Recovery in coal mining	4
Roof action and roof control	5
Explanation of curves	6
Description of mines	10
Mine 56	10
Mining method	10
Pillar extraction	11
Roof action	13
Recovery	13
Classification of employees	13
Summary	14
Mine 57	15
Mining method	15
Pillar extraction	16
Roof action	17
Recovery	18
Classification of employees	18
Summary	19
Mine 58	19
Mining method	20
Pillar extraction	20
Roof action	22
Recovery	22
Classification of employees	23
Summary	24

---

[1] Mining engineer, Coal Branch, Fuels Technology Division, Region VIII, Bureau of Mines, Pittsburgh, Pa.

[2] Principal coal mining engineer, Fuels and Explosives Division, Bureau of Mines, Pittsburgh, Pa.

[3] Mining engineer, Office of Coal Technology Coordinator, Bureau of Mines, Washington, D. C.

Information Circular 7631

CONTENTS (Cont.)

Page

Description of mines (Cont.)
- Mine 59 24
  - Mining method 25
  - Pillar extraction 25
  - Roof action 27
  - Recovery 27
  - Classification of employees 28
  - Summary 29
- Mine 60 29
  - Mining method 30
  - Pillar extraction 30
  - Roof action 32
  - Recovery 32
  - Classification of employees 33
  - Summary 34
- Mine 61 35
  - Mining method 35
  - Pillar extraction 36
  - Roof action 37
  - Recovery 37
  - Classification of employees 38
  - Summary 39
- Mine 62 39
  - Mining method 40
  - Pillar extraction 40
  - Roof action 42
  - Classification of employees 42
  - Summary 43
- Mine 63 43
  - Mining method 43
  - Pillar extraction 44
  - Roof action 45
  - Recovery 46
  - Classification of employees 46
  - Summary 47
- Mine 64 47
  - Mining method 48
  - Pillar extraction 48
  - Roof action 49
  - Classification of employees 50
  - Summary 51
- Mine 65 51
  - Mining method 51
  - Pillar extraction 52
  - Roof action 53
  - Classification of employees 54
  - Summary 55

CONTENTS (Cont.)

Page

Description of mines (Cont.)
Mine 66 55
Mining method 55
Pillar extraction 56
Roof action 57
Recovery 58
Classification of employees 58
Summary 59
Mine 67 60
Mining method 60
Pillar extraction 61
Roof action 62
Recovery 62
Classification of employees 63
Summary 63

TABLE

1. Summary of performance of mobile loading units and conveyor units 64

ILLUSTRATIONS

Follows page

Fig.

1. Relation of man-hours per ton of raw coal and man-shifts (8-hours) per 1,000 tons of raw coal to thickness of bed. Pillars extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.) 6
2. Relation of man-hours per ton of raw coal and man-shifts (8-hours) per 1,000 tons of raw coal to thickness of bed. Pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.) 6
3. Relation of man-hours per ton of raw coal on mechanized units and man-shifts per 1,000 tons of raw coal to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.) 8
4. Relation of man-hours per ton of raw coal and man-shifts per 1,000 tons of raw coal, total underground labor, to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.) 8
5. Relation of man-hours per ton of raw coal and man-shifts per 1,000 tons of raw coal, total surface and underground labor, to thickness of bed. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.) 8
6. Relation of man-hours per ton of raw coal to thickness of bed (or mining height), inches. Pillars extracted, conveyors. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.) 8

ILLUSTRATIONS (Cont.)

Fig. — Follows page

7. Relation of tons of raw coal loaded per mobile loading unit per hour and shift (8-hours) to thickness of coal bed. Pillars extracted and pillars not extracted. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.) 8
8. Relation of raw coal loaded per conveyor unit per hour to thickness of coal bed (or mining height). Pillars extracted. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.) 10
9. Section of coal bed, roof and bottom rock at mine 56 .. 10
10. Mining method at mine 56 10
11. Pillar extraction at mine 56 10
12. Section of coal bed, overburden, and bottom rock at mine 57 14
13. Mining method at mine 57 14
14. Pillar extraction at mine 57 16
15. Section of coal bed, roof, and bottom rock at mine 58.. 20
16. Mining method at mine 58 20
17. Pillar extraction and timbering at mine 58 20
18. Section of coal bed and overburden at mine 59 24
19. Mining method at mine 59 24
20. Pillar extraction and timbering at mine 59 24
21. Section of overburden and coal bed at mine 60 30
22. Mining method at mine 60 30
23. Pillar extraction at mine 60 30
24. Section of overburden and coal bed at mine 61 34
25. Mining method at mine 61 34
26. Pillar extraction at mine 61 36
27. Section of overburden and coal bed at mine 62 40
28. Mining method at mine 62 40
29. Timbering details and cutting sequence in pillars at mine 62 40
30. Section of overburden and coal bed at mine 63 42
31. Mining method at mine 63 44
32. Pillar extraction at mine 63 44
33. Section of coal bed and overburden at mine 64 48
34. Mining method at mine 64 48
35. Pillar extraction and roof-support method at mine 64 .. 48
36. Section of overburden and coal bed at mine 65 50
37. Mining method at mine 65 52
38. Timbering details and sequence of lifts in pillars at mine 65 52
39. Section of overburden and coal bed at mine 66 54
40. Mining method at mine 66 54
41. Timbering details and sequence of lifts in pillars at mine 66 56
42. Section of coal bed and overburden at mine 67 60
43. Mining method at mine 67 60
44. Pillar extraction at mine 67 60

INTRODUCTION

This is the sixth of a series of publications that describe methods and practices in mining coal mechanically.[4] These studies were endorsed by the Coal Conservation Committee of the National Bituminous Coal Advisory Council. The six reports issued to date contain detailed descriptions of mining operations at 67 coal mines in all the important coal fields in the United States. Progress reports 4, 5, and 6 have been confined to operations practicing pillar extraction with mechanized equipment. Descriptions of mines 56 to 67 are included in this report.

Studies of mechanized operations at many mines where pillars are not extracted, descriptions of which are not included in these reports, were made to obtain additional data for comparison with operating performance at mines where pillars are extracted.

The objective of these studies is to emphasize the following phases of pillar extraction:

1. Percentage of recovery in pillar extraction in panels and over-all recovery obtained in various mines using different mining methods.

2. Roof action, including methods of supporting the roof in pillar extraction and the methods employed to effect roof falls in mined-out areas.

3. Comparison of performance of mechanized units in mines where pillars are extracted and in mines where pillars are not extracted.

4. Descriptions of methods of extracting pillars at mines studied that can be understood by persons in the mining industry and others as well.

---

[4] Toenges, Albert L., and Anderson, Robert L., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 1: Bureau of Mines Inf. Circ. 7014, 1938, 56 pp.
Toenges, Albert L., and Jones, Frank A., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 2: Bureau of Mines Inf. Circ. 7067, 1939, 58 pp.
Toenges, Albert L., and Maize, Earl R., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 3: Bureau of Mines Inf. Circ. 7178, 1941, 43 pp.
Toenges, Albert L., Maize, Earl R., and Jones, Frank A., Multiple-Shift Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 4: Extraction of Pillars with Mechanized Equipment: Bureau of Mines Inf. Circ. 7223, 1942, 59 pp.
Turnbull, Louis A., and Toenges, Albert L., Mechanical Mining in Some Bituminous-Coal Mines. Progress Report 5: Extraction of Pillars with Mechanized Equipment: Bureau of Mines Inf. Circ. 7527, 1949, 59 pp.

From data collected at mines in different areas and under various conditions, tentative conclusions have been drawn and are discussed in this report.

Data contained in the summaries of mine descriptions and information correlated in the curves in this report may prove helpful in planning future mining operations and in evaluating performances of mines operated at present.

ACKNOWLEDGMENTS

The information relative to mine operations described in this report was obtained through the courtesy and cooperation of the officials of the companies whose mines are described. Consent of the executives to publish these data was obtained.

SUMMARY AND CONCLUSIONS

The curves and conclusions given in this report are based upon detailed studies of mining operations at more than 80 coal mines in all the important coal fields of the United States. Conclusions regarding: (1) Effective methods of extracting pillars, (2) comparisons of methods of mining, (3) recovery, (4) roof action and roof control, and (5) comparisons of performances at mines where pillars are extracted and mines where pillars are not extracted, follow:

1. The open-end method of pillar extraction, which is the most common method used, results in the highest percentage of recovery. The pocket-and-fender method also has widespread use. However, various amounts of coal are lost in thin fenders or small stumps left for temporary roof support between the pockets or lifts and gob area during pillar mining. Therefore, the pocket-and-fender method generally does not provide as high recovery as the open-end method. However, there are many mines where the open-end method cannot be applied because of adverse roof conditions.

2. The type of loading equipment most commonly used in the mines studied is mobile loading devices. Hand-loaded conveyors and conveyors equipped with self-loading heads are in use in many of the mines studied, especially in thin and dipping coal beds. Conveyor operations often obtain better recovery but generally lower performance in tons per man per shift than operations employing mobile loading equipment. Recovery is better because wide roadways are not necessary for conveyor equipment and closer timbering can be used, thereby providing more effective roof control.

3. From data correlated in the studies, over-all recovery at mines where pillars are extracted ranges from 70 to 85 percent. Recovery in panels ranges from 75 to 95 percent. Recovery in mines where pillars are extracted ranges from 10 to 50 percent more than in mines operated under similar physical conditions but where pillars are not extracted. Coal lost in mining may be divided into two groups: (1) Coal left in barrier pillars as required by State and local laws, coal left under surface structures, coal lost because of physical conditions in and surrounding the coal bed, and coal abandoned because of the topography. These losses cannot be avoided by individual operators. (2) Coal lost in mining. This loss includes coal frequently left in entry chain and barrier pillars, room pillars, top and bottom coal left unmined, coal lost in closely adjacent coal beds underlying or overlying the bed mined, coal between mine workings and outcrops, and waste of coal in mining, much of which can be avoided by individual operators.

The development of efficient mechanical coal-cleaning processes and introduction of roof bolting in coal mines has encouraged a trend away from selective mining in individual as well as groups of coal beds. Full-seam mining is gaining popularity in the thicker coal beds. A decline in selective mining would benefit conservation materially, because much coal lost in selective mining cannot be recovered.

4. The studies indicate that the most difficult problem encountered in extracting pillars with mechanized equipment is the effective control of not only the immediate roof but the entire overlying strata. The void created in the strata is partly filled with caved rock from the immediate overlying strata and partly by subsidence of the remaining overburden. Well-planned mining methods derived from extensive knowledge of pillar mining as well as experience with local physical conditions are essential. The speed, regularity, and precision with which pillars are extracted help to obtain regular breaks and caving of overlying strata along established pillar lines, thus relieving and preventing excessive weight at the coal faces. In some mines, advantage is taken of natural cleats in roof rock to obtain frequent and systematic roof falls. Some of the more serious adverse conditions arising in pillar extraction are the results of the failure to mine all stumps, pillars, or larger blocks of coal as a section is retreated. Squeezes and other unfavorable mining conditions may arise, which result in abandonment of a pillar line and subsequent loss of large areas of coal.

5. The studies show that the average labor employed underground, in man-hours per ton at mines where mobile loading devices are used, is greater where pillars are extracted than where pillars are not extracted. The difference ranges from 0.10 man-hour per ton for a bed 36 inches thick to 0.19 man-hour per ton for a bed 72 inches thick and to 0.22 man-hour per ton for a bed 120 inches thick.

The average production per hour per mobile loading unit is less where pillars are extracted than where pillars are not extracted. The difference ranges from 2.0 tons per hour for a bed 36 inches thick to 2.5 tons per hour for a bed 72 inches thick and to 7.5 tons per hour for a bed 120 inches thick. Production per conveyor unit per hour appears to be about the same in pillar and nonpillar mining.

Some factors that tend to offset the higher labor costs in operations where pillar extraction is accomplished with mobile loading equipment are:

a. Smaller initial capital investment is required per ton in shafts, slopes, surface plants, haulageways and airways, track, trolley lines, and power-transmission lines because greater tonnages are recovered from the areas mined.

b. More tons are recovered per acre; therefore, depletion per ton is less; and, where high real estate taxes have been paid on coal land owned over a period of years, the tax cost per ton of coal produced is less.

In general, coal mining is a highly competitive industry, and the margin of profit per ton of coal often is small. Therefore, economic factors cause many mining companies to adopt methods of mining that will provide maximum daily operating efficiency with the result that recovery is low, and individual company coal reserves, as well as the national fuel reserves, are wasted. The methods used may provide for lower daily mining costs, but otherwise may prove more costly over a period of years. Notable exceptions are those companies operating in coal beds containing premium-quality coals, in areas where coal reserves are limited, or where coal lands are leased and a maximum percent of recovery is required by the lessor.

The benefits of pillar extraction in conservation of a valuable natural resource are obvious and are particularly important to the country's economy in areas producing high-quality coals suitable for metallurgical use or for special purposes other than steam raising or space heating. Therefore, companies operating in these and other areas should be encouraged to increase their recovery by pillar extraction, or by developing new high-recovery methods of mining that will be adaptable to continuous mining devices and other proven mining equipment.

RECOVERY IN COAL MINING

In coal mining, the term "percentage of recovery" refers to that portion of the total amount of coal originally in place in a coal bed in a prescribed area that is mined and transported to the surface. This percentage may represent total coal mined during one or more stages of mining, or coal recovered in each individual stage leading to final abandonment of the area after mining is considered completed.

The area prescribed for computing percentage of recovery depends upon the purpose for which the recovery figure is intended and may describe a portion of a mine such as one panel, the entire area of the mine, a tract of land, or an entire coal field.

In computing or estimating percentage of recovery, several factors must be employed. An estimate of the reserve of coal originally in place must be made from known values of coal-bed thicknesses (minus thickness of partings) and of specific gravity of the coal in the prescribed area. These values may be changed and their number increased as exploration and development progress. All areas left for barriers should be included in the original reserve of coal. Coal recovered is the weight of raw coal mined and transported to the surface, exclusive of such foreign materials as top and bottom rock and major partings in the coal bed.

The grade and quality of coal sometimes induces selective mining in some areas. That is, portions of coal beds or areas of coal fields comprising low-grade coal may have commercial value and be minable only during times of heavy market demand. High production costs may result from adverse mining conditions, such as decrease in the thickness of the coal bed, weak roof or soft bottom that can be remedied by leaving top or bottom coal, and excessive surface and ground water. These increased costs may induce selective mining in some areas. Coal left unmined during selective mining usually is lost for future mining, and no attempt is made for further recovery.

The value of the coal in place and the quantity of reserves in an area often influence the method of mining and, consequently, recovery. Coals qualifying for metallurgical coke, byproduct use, or other special purposes usually are in demand and many of the reserves of this grade of coal are rapidly becoming depleted. Therefore, several coal mining companies, some of which operate captive mines that produce this type of coal, are not seriously hampered by competition and are conservation minded. On the other hand, mining companies operating in fields of lower-quality coal where coal reserves are large or where competition is severe place special emphasis on maintaining minimum possible mining costs. Except where lessors of coal lands require a definite percentage of recovery as a minimum standard, many of these companies give little regard to conservation. These companies usually follow the room-and-pillar system of mining, whereby rooms are driven as wide as safety permits. Little or no attempt is made to recover the narrow pillars between rooms or to recover entry, chain, and barrier pillars.

For various reasons, percentage of recovery was not available at some of the mines included in this study. Many companies do not keep separate records of the tonnage of coal mined from individual panels or specific areas of a mine. Therefore, percentage of recovery at these mines cannot be accurately computed until the mine is finally abandoned and only then if a record of the total tons produced is available.

Some companies estimate recovery on the basis of areas mined out, as compared to the over-all area of the coal in which mining has been completed. This method is obviously inaccurate because the various losses in mining cannot be accounted for. For these reasons, many recovery figures claimed by mining companies are too high to be accepted as correct. Obviously, the accuracy of estimates of percentage of recovery depends upon the criteria used in making the estimate.

ROOF ACTION AND ROOF CONTROL

It is generally agreed in the coal mining industry that in mining coal successfully: (1) Enough coal must be removed to permit the roof and overburden to cave and subside completely; or (2) enough solid coal must be left in place to support the overburden, at least until mining operations in a given area are abandoned. In the first method, 30 to 60 percent of the coal mined is from development work, and the remaining production is from systematic pillar robbing or pillar extraction. In the second method, very little coal is recovered from pillars. The first method requires that mine section layouts be designed so that systematic pillar extraction can be planned in advance. Development and pillar-extraction plans usually are dependent upon the operator's knowledge of mining conditions in the area and upon the type of equipment to be used. Other factors that govern mine layouts are mining costs, production possibilities, recovery of coal, and safety of employees and equipment.

The two systems of pillar extraction most generally used are the block and room-and-pillar. With the block system, which is more generally used in thick coal beds, over half the production usually is from pillars. In the room-and-pillar system, which is used in both thick and thin coal beds, over half the production usually is from entries, rooms, and crosscuts.

The open-end and pocket-and-fender methods are most generally used in pillar extraction. Where the open-end method is used, cuts or lifts are mined from one or two gob sides of a pillar and no fenders or stumps of coal are left adjacent to the gob as the lift is advanced. In the pocket-and-fender method, lifts are mined in the same way as in the open-end method, except that a fender of coal or a series of small coal stumps is left adjacent to the gob as the lift is advanced. After the lift is completed, the fender or stumps of coal are blasted, and sometimes part of this coal is recovered.

In pillar mining, the roof at the pillar line is supported by timbers, fenders of coal, or stumps of coal. Timbers, where used, comprise rows of breaker props, wood crossbars, or wood cribs. These roof-support methods often are used in combinations of two or more, depending upon roof conditions. The roof over mined-out areas must cave as pillar extraction progresses. Caving relieves weight that otherwise would be transferred to timbers and solid coal along the pillar line.

Some of the more serious hazards observed in pillar extraction are the results of voluntary or accidental failure to mine all the coal as mining in a section retreats. Large unmined blocks of coal, pillars, or portions of pillars, too large to crush as the pillar line is retreated, prevent caving for various distances around the unmined blocks. When caving does not occur, weight is transferred to timbers and solid coal surrounding the mined area, particularly along the pillar line. This weight often causes bottom heaving, squeezing, and other unfavorable mining conditions, and, in extreme cases, abandonment of the pillar line; sometimes the loss of the entire section may result. A squeeze in a section of a mine usually creates difficult and hazardous mining conditions in adjacent panels and often necessitates leaving large barrier pillars around the squeezed area. Over-all recovery is greatly reduced when these conditions develop.

In pillar extraction, results are best when both development and pillar mining are planned in advance and executed systematically. Regularity of operations and speed of retreat along a pillar line usually influence roof action and the quantity of materials and labor required to control the roof. Intermittent operations often cause serious roof and bottom conditions. As a result, extra clean up and timbering are often required each time work is resumed.

EXPLANATION OF CURVES

The following curves are based upon detailed studies of mechanized mining in more than 80 bituminous coal mines in every important coal field in the United States. The studies include loading practices with mobile loading devices, both trackless and track-mounted; conveyors equipped with self-loading heads; and hand-loaded chain and shaking conveyors.

The points on which the curves are based were determined by computing weighted average production and man-hours per ton of raw coal for groups of mines operated under similar physical conditions and in similar mining heights. Mining height sometimes is used instead of coal-bed thickness because some companies do not practice full-seam mining, while others mine draw rock, bony coal roof, or thick partings with the coal. Mining height, rather than coal-bed thickness, is often the determining factor governing size and capacity of loading machines and intermediate haulage equipment. Therefore, the curves represent the average production and man-hours per ton of raw coal for various mining heights in coal beds in different areas. Points computed from operating data at any one mine may deviate above or below points on the curves; but, in planning new operations, it can be expected that mining performance for a given bed thickness (or mining height) with the several types of loading equipment will be reasonably near the curves. Raw coal is used as the basis for comparing performances because the amount of reject varies at different mines. Production of clean coal can be determined by applying the percentage of reject in the coal.

Although an employee may actually work only 6 hours at the face, the total number of hours in the shift for which he was paid (7, 8, or 9) was used in all computations to obtain man-hours per ton and output per unit per hour.

The curves in figure 1 show the relation of man-hours per ton of raw coal and man-shifts (8-hour) per 1,000 tons of raw coal produced to the thickness of the coal bed (or mining height) for labor employed at the face on mobile loading units; for total labor employed underground; and for total employees, surface and underground, for mines in which pillars are extracted. An example of the man-hours required to produce a ton of coal in a bed 60 inches thick, using mobile loading machines and extracting pillars, follows:

	Man-hours per ton
Employees, mechanized units, raw coal	0.58
Other underground employees, raw coal	.25
Surface employees, raw coal	.18
Total employees, raw coal	1.01
Total employees, clean coal	[1] 1.19

---

[1] Arbitrary figure for recovery of clean coal at cleaning plant, 85 percent of raw coal.

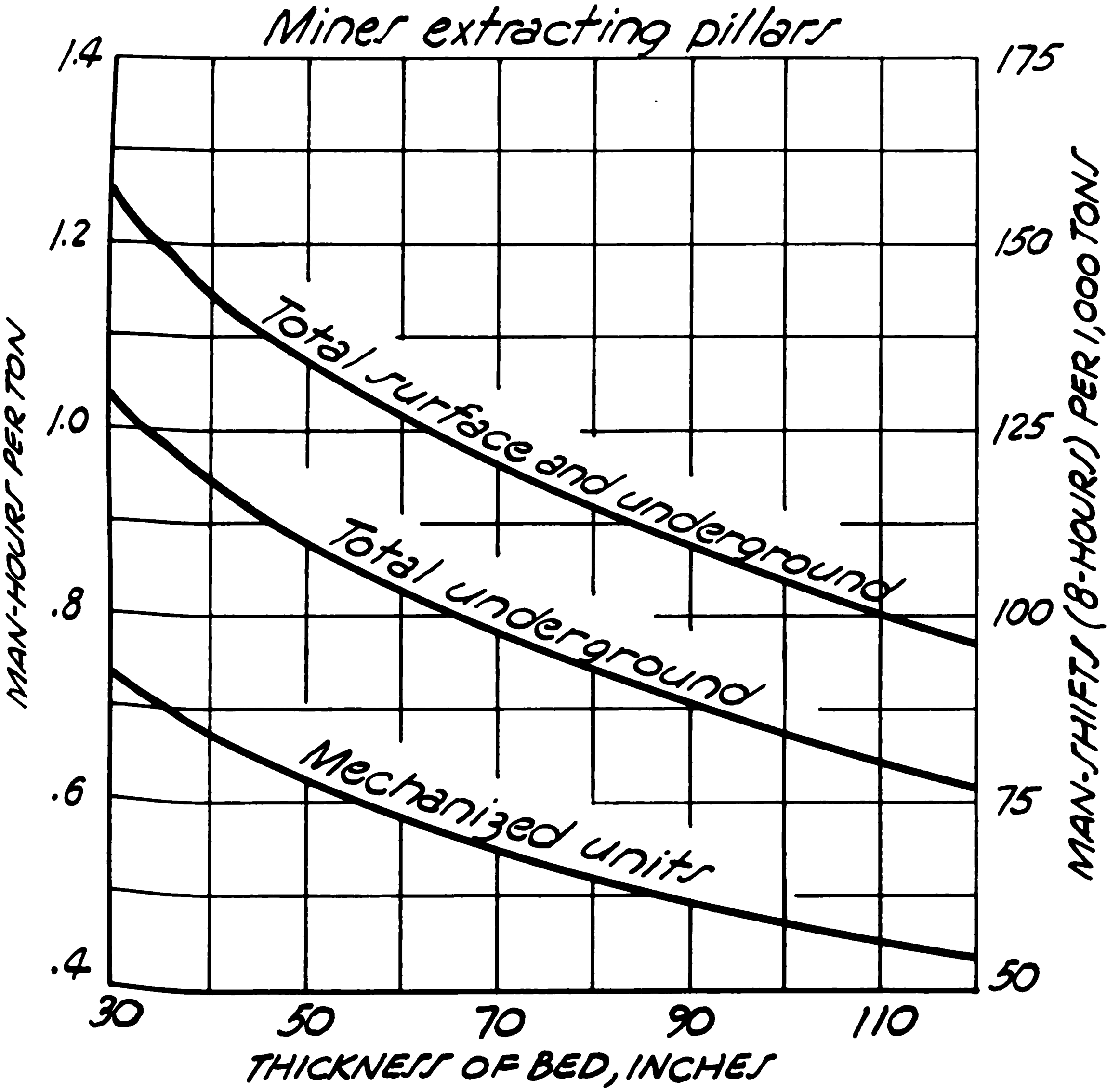


Figure 1. - Relation of man-hours per ton of raw coal and man-shifts (8-hours) per 1,000 tons of raw coal to thickness of bed. Pillars extracted. Mobile loading machines. (Man-hours computed from full 7- , 8- , or 9-hour shifts.)

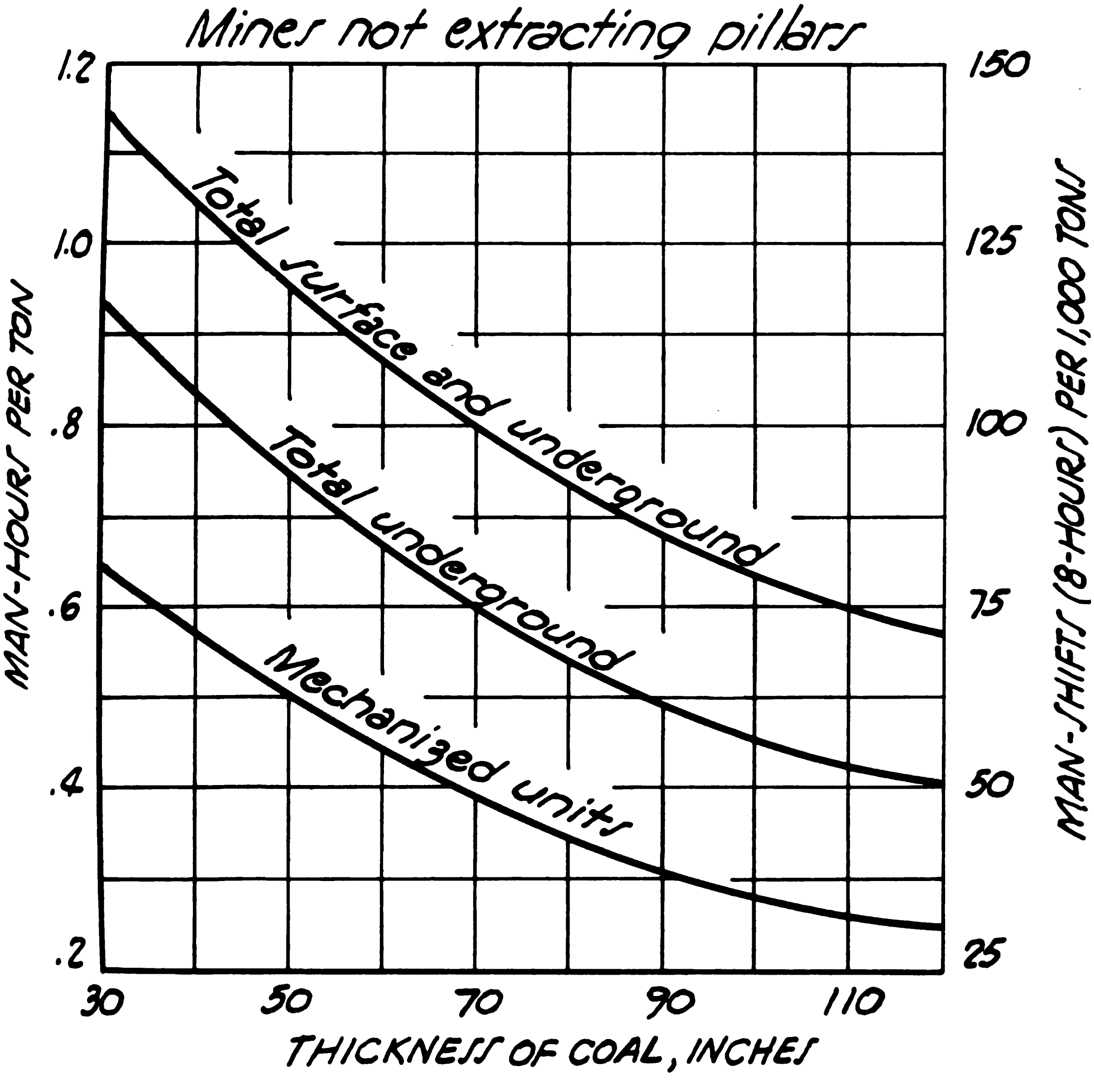


Figure 2. - Relation of man-hours per ton of raw coal and man-shifts (8-hours) per 1,000 tons of raw coal to thickness of bed. Pillars not extracted. Mobile loading machines. (Man-hours computed from full 7- , 8- , or 9-hour shifts.)

Man-hours per ton for total underground employees at individual mines included in these curves range from 0.27 man-hour per ton less to 0.20 man-hour per ton more than the weighted average in 45-inch coal. At other mines, the range is from 0.34 man-hour per ton less to 0.20 man-hour per ton more than weighted average in 84-inch coal. The mine operated in 45-inch coal with better-than-average performance is indicative of superior physical conditions and well-coordinated mining with medium-capacity equipment. The better-than-average performance in 84-inch coal represents a mine in which effective bolting of a weak roof, belt haulage in both panels and main entries, and coordinated use of high-capacity equipment have been combined to give efficient operation. These mines have attained high performance without sacrifice of recovery.

Differences in man-hours per ton for surface employees range from 0.21 man-hour for 30-inch coal to 0.16 man-hour for 120-inch coal. The difference largely is due to the use of more shopmen at mines in thinner coal. Lower-capacity mining equipment is used in thin coal than in thick coal. More machines are needed for an equivalent production of coal in thin beds and, therefore, more men are needed for periodic major repairs on mining machinery.

Man-shifts per 1,000 tons of raw coal may be used to estimate the number and distribution of employees required for a new mine or to evaluate or compare the performances at mines where pillars are extracted. An example of the man-shifts required to produce 2,500 tons of raw coal in a bed 60 inches thick, using mobile loading machines and extracting pillars, follows:

	Man-shifts per 1,000 tons of raw coal	Man-shifts per 2,500 tons of raw coal[1]
Employees on mechanized units	73	182
Other underground employees	31	78
Surface employees	23	58
Total employees	127	318

[1] Number of employees for 1,000-ton operation multiplied by 2.5 or comparative size of mine desired.

The curves in figure 2 show the relation of man-hours per ton of raw coal and man-shifts (8-hour) per 1,000 tons of raw coal to the thickness of the coal bed (or mining height) for labor employed at the face on mobile loading units; for total labor employed underground; and for total employees, surface and underground, for mines where pillars are not extracted. An example of the man-hours required to produce a ton of raw coal in a bed 60 inches thick, using mobile loading machines and not extracting pillars, follows:

	Man-hours per ton
Employees, mechanized units, raw coal	0.44
Other underground employees	.23
Surface employees, raw coal	.20
Total employees, raw coal	.87
Total employees, clean coal	[1]1.02

[1] Arbitrary figure for recovery of clean coal at cleaning plant, 85 percent of raw coal.

Man-hours per ton for total underground employees at individual mines included in these curves range from 0.17 man-hour per ton less to 0.12 man-hour per ton more than the weighted average for 42-inch coal. At other mines these values range from 0.10 man-hour per ton less for 84-inch coal to 0.15 man-hour per ton more for 96-inch coal than the weighted average for these bed thicknesses. These two mines, with better-than-average performances, represent operations in coal not of premium quality and where low mining costs are foremost in competing with neighboring coal operations. Little attention is given to recovery.

Differences in man-hours per ton for surface employees range from 0.21 man-hour for 30-inch coal to 0.17 man-hour for 120-inch coal. The difference largely is due to the use of more shopmen in mines in thinner coal. Lower-capacity mining equipment is used in thin coal than in thick coal. More machines are needed for an equivalent production of coal in thin beds and, therefore, more men are needed for periodic major repairs on mining machinery.

Man-shifts per 1,000 tons of raw coal may be used to estimate the number and distribution of employees required for a new mine or to evaluate or compare performances at mines where pillars are not extracted. An example of the man-shifts required to produce 2,500 tons of raw coal in a bed 60 inches thick, using mobile loading machines and not extracting pillars, follows:

	Man-shifts per 1,000 tons of raw coal	Man-shifts per 2,500 tons of raw coal[1/]
Employees on mechanized units	55	137
Other underground employees	30	75
Surface employees	24	60
Total employees	109	272

1/ Number of employees for 1,000-ton operation multiplied by 2.5 or comparative size of mine desired.

The curves in figure 3 show the relation of man-hours per ton of raw coal and man-shifts (8-hour) per 1,000 tons of raw coal on mechanized units using mobile loading machines to thickness of coal bed (or mining height) at mines where pillars are extracted and at mines where pillars are not extracted. These curves show that the man-hours per ton at the face are higher in pillar extraction than where pillars are not extracted. Consequently, the number of men at the face is higher at mines where pillars are extracted. The difference increases as the mining height increases. Difference in man-hours per ton ranges from 0.10 man-hour per ton for 36 inches of coal to 0.16 man-hour per ton for 72 inches and 0.19 man-hour per ton for 120 inches. Difference in man-shifts per 1,000 tons ranges from 12 man-shifts for 36 inches of coal to 20 man-shifts for 72 inches and 24 man-shifts for 120 inches. Roof control generally is a greater problem where pillars are extracted, and the differences shown on the curves are due to additional time spent in timbering to control the roof and for clean-up work in active sections. More men are required to set timbers in thick-bed mining than in thin-bed mining.

The curves in figure 4 show the relation of man-hours per ton of raw coal and man-shifts (8-hour) per 1,000 tons of raw coal for total underground labor using mobile loading machines to thickness of coal bed (or mining height) at mines where pillars are extracted and mines where pillars are not extracted. Man-hours per ton are more where pillars are extracted, and the difference ranges from 0.10 man-hour for 36-inch coal to 0.19 man-hour for 72-inch coal and to 0.22 man-hour for 120-inch

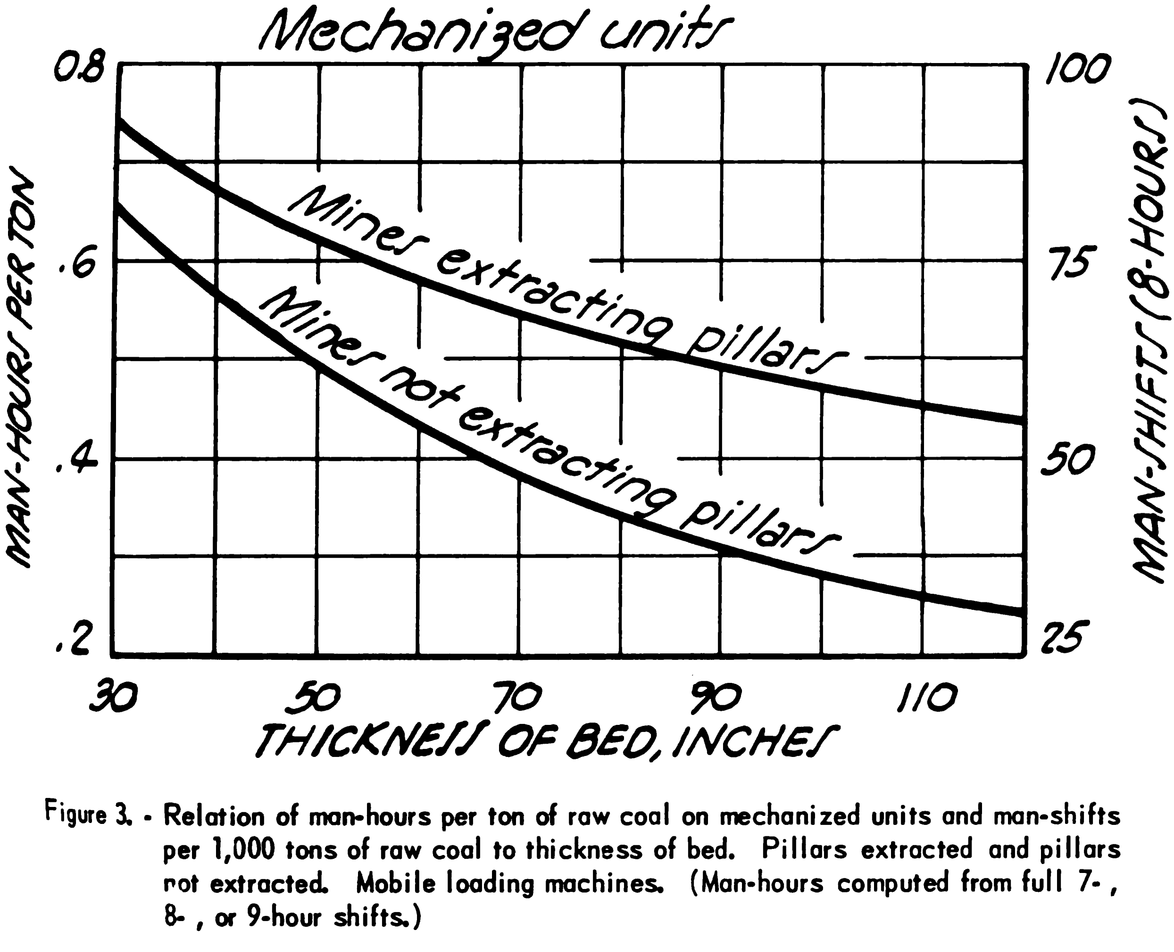


Figure 3. - Relation of man-hours per ton of raw coal on mechanized units and man-shifts per 1,000 tons of raw coal to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

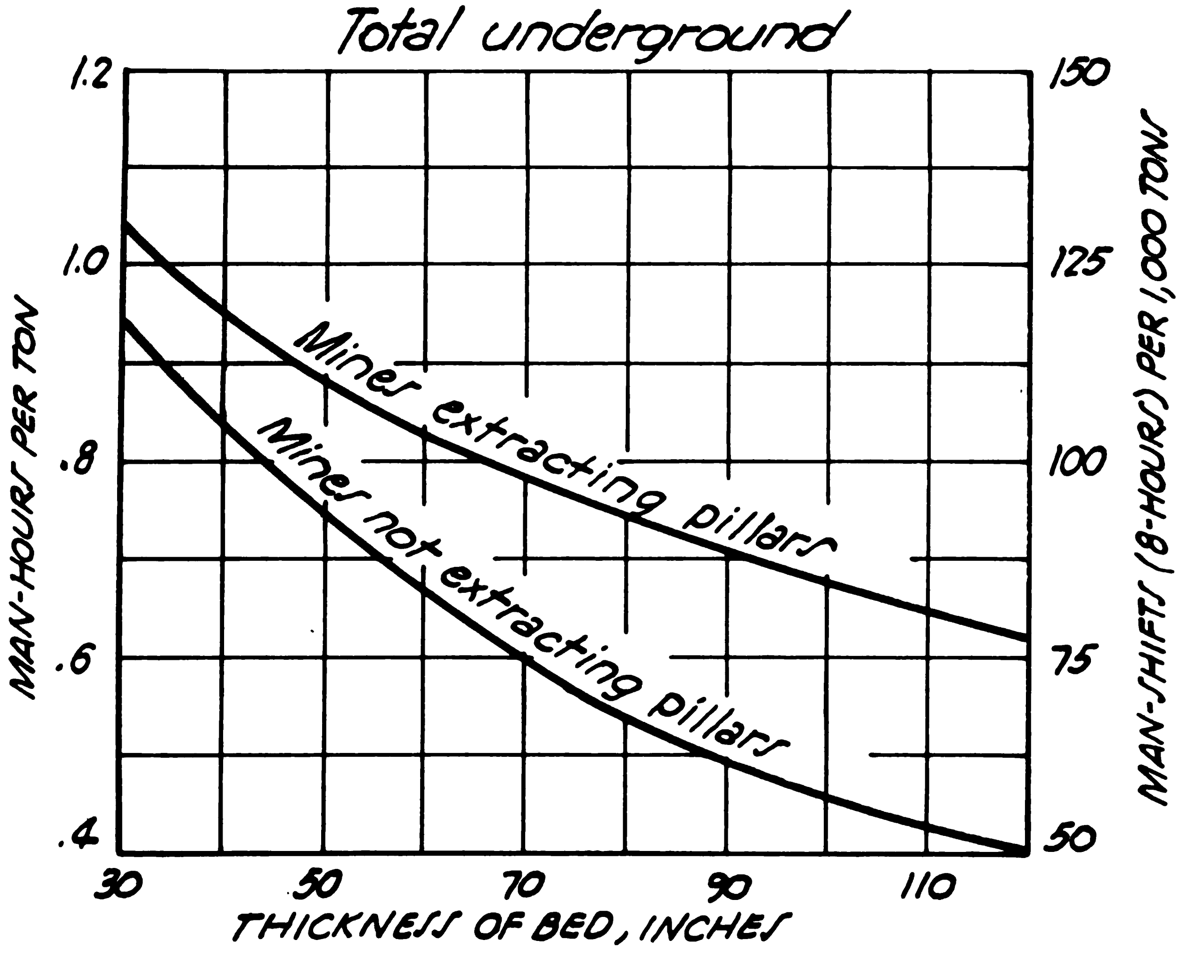


Figure 4. - Relation of man-hours per ton of raw coal and man-shifts per 1,000 tons of raw coal, total underground labor, to thickness of bed. Pillars extracted and pillars not extracted. Mobile loading machines. (Man-hours computed from full 7-, 8-, or 9-hour shifts.)

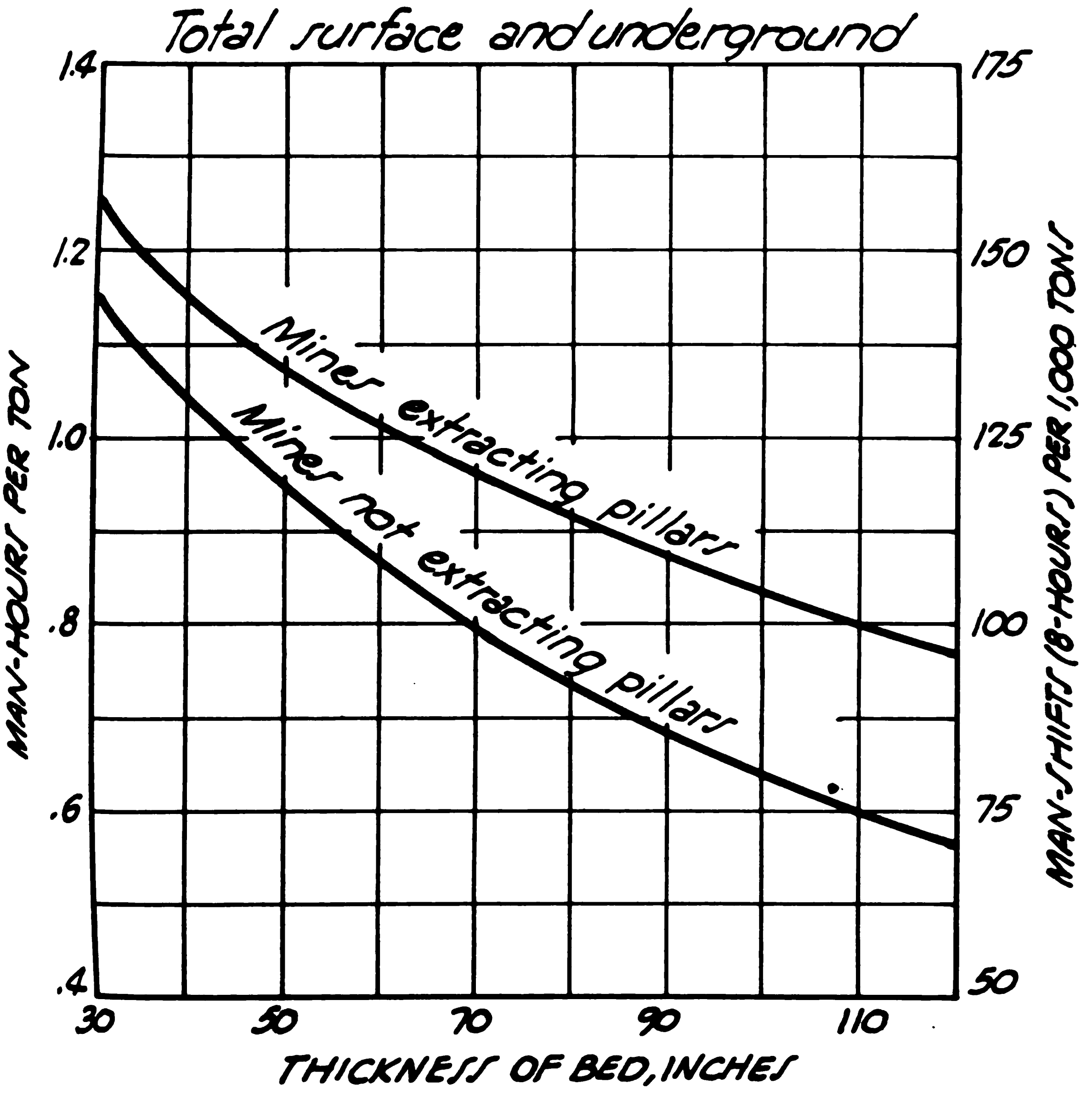


Figure 5. - Relation of man-hours per ton of raw coal and man-shifts per 1,000 tons of raw coal, total surface and underground labor, to thickness of bed. Mobile loading machines. (Man-hours computed from full 7- , 8- , or 9-hour shifts.)

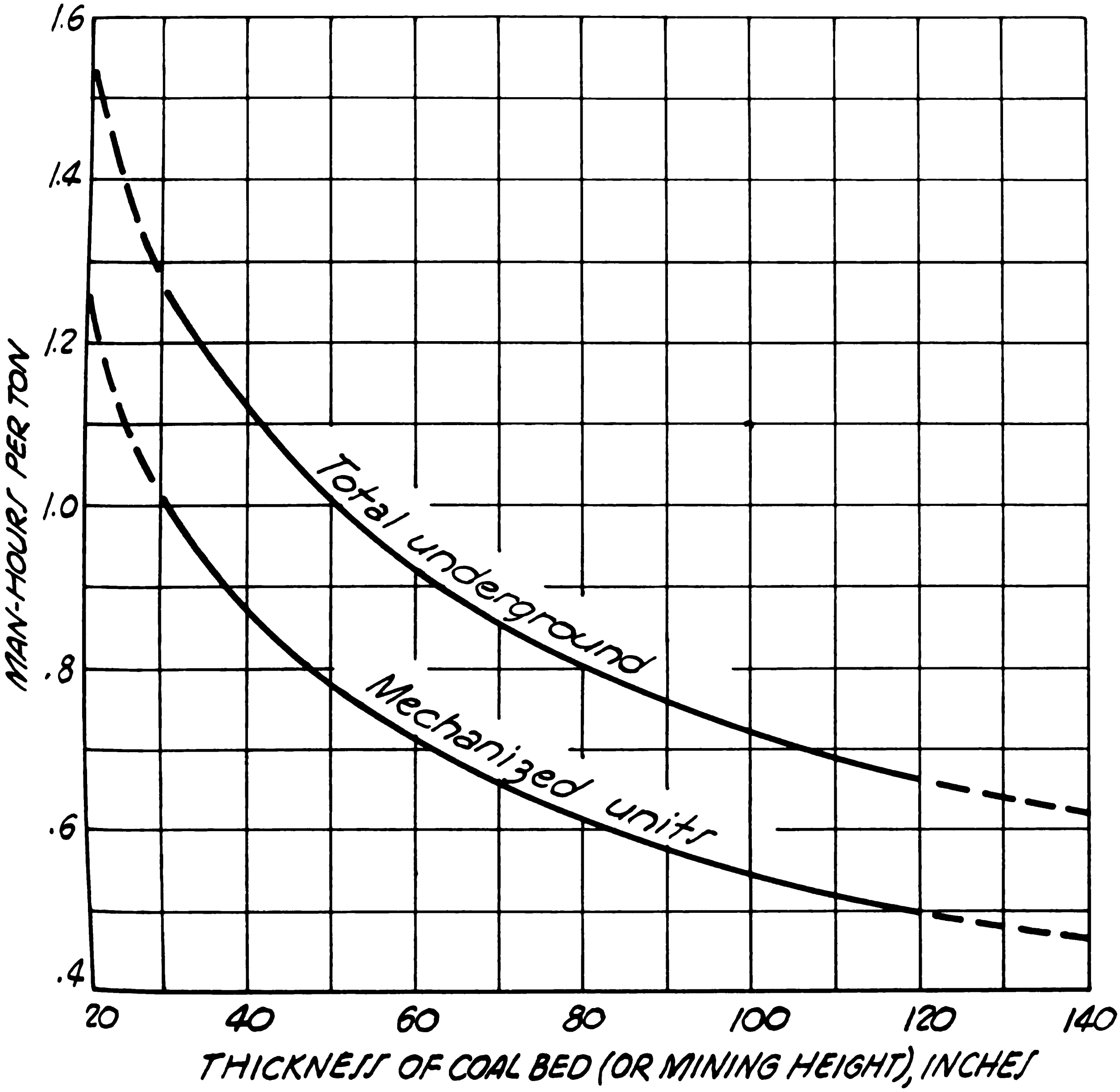


Figure 6. - Relation of man-hours per ton of raw coal to thickness of bed (or mining height), inches. Pillars extracted, conveyors. (Man-hours per ton computed from full 7-, 8-, or 9-hour shifts.)

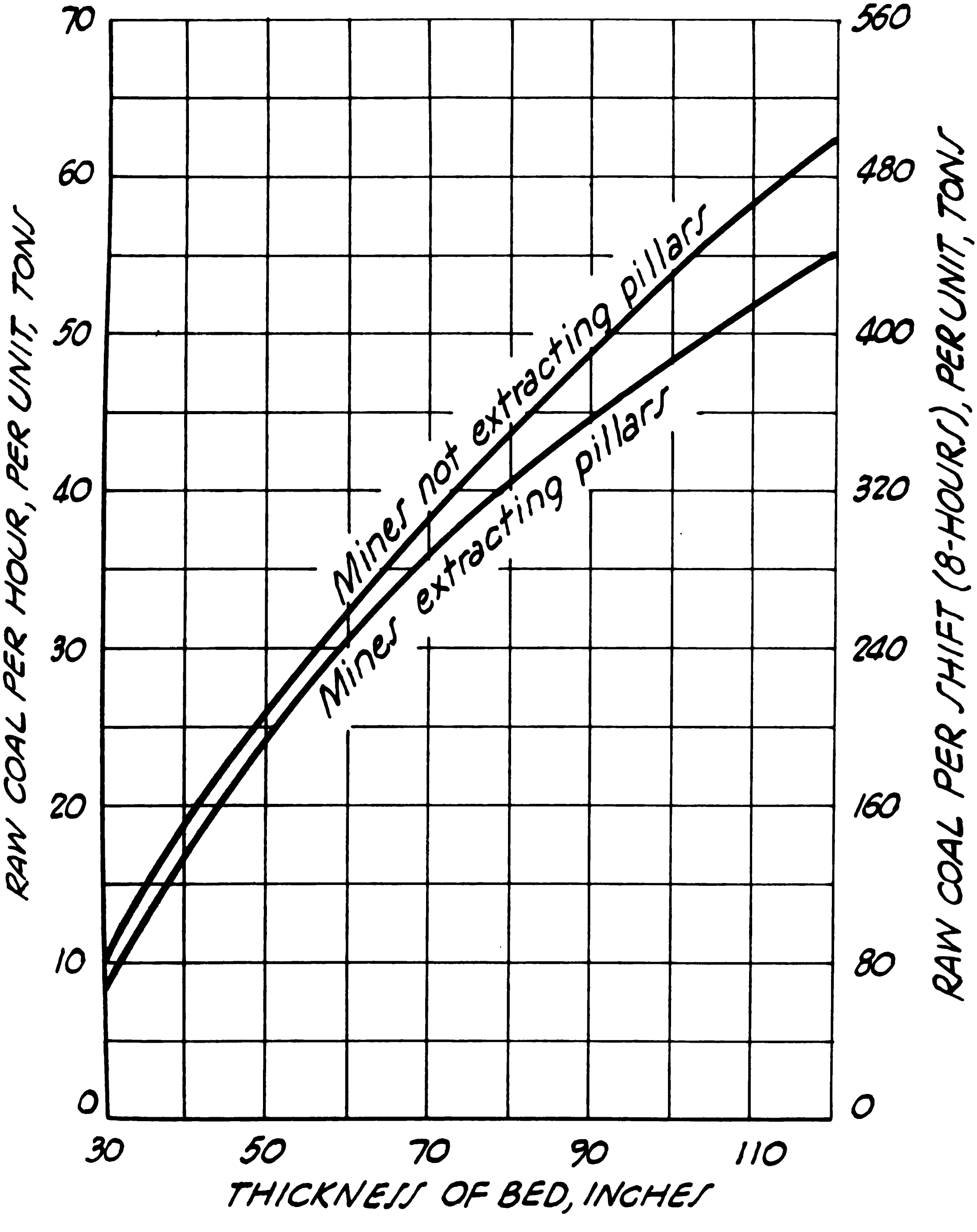


Figure 7. - Relation of tons of raw coal loaded per mobile loading unit per hour and per shift (8-hours) to thickness of coal bed. Pillars extracted and pillars not extracted. (Tons per hour computed from full 7-, 8-, or 9-hour shifts.)

coal. Man-shifts per 1,000 tons are more where pillars are extracted, and the difference ranges from 12 man-shifts for 36 inches of coal to 24 man-shifts for 72 inches and 27 man-shifts for 120 inches.

In figure 5, the curves show the relation of man-hours per ton of raw coal and man-shifts (8-hour) per 1,000 tons of raw coal for total employees, surface and underground, using mobile loading machines to thickness of coal bed (or mining height) at mines where pillars are extracted and at mines where pillars are not extracted. Man-hours per ton are more where pillars are extracted, and this difference ranges from 0.10 man-hour for 36 inches of coal to 0.17 man-hour for 72 inches of coal to 0.20 man-hour for 120 inches of coal. Man-shifts per 1,000 tons are more where pillars are extracted, and the difference ranges from 12 man-shifts for 36 inches of coal to 21 man-shifts for 72 inches of coal to 25 man-shifts for 120 inches of coal.

In figure 6, the relation of man-hours per ton of raw coal produced to the thickness of the coal bed (or mining height) for labor employed at the face on conveyor units and total labor employed underground for mines where pillars are extracted is shown. An example of the man-hours required to produce a ton of coal in a bed 42 inches thick, using conveyors and extracting pillars, follows:

	Man-hours per ton
Employees, mechanized units, raw coal	0.85
Other underground employees, raw coal	.24
Surface employees	1/.20
Total employees, raw coal	1.29
Total employees, clean coal	2/1.52

1/ Weighted average surface labor, in man-hours, for mines studied.

2/ Estimated average refuse at cleaning plant, 15 percent of raw coal.

Man-hours per ton for total underground employees at individual mines included in these curves range from 0.30 man-hour per ton less than the weighted average for 54 inches of coal to 0.57 man-hour per ton more than the weighted average for 62 inches of coal. The performance at the first mine represents efficient operation in a mine having superior physical conditions and short haulage. The second mine is operated under thick cover and unusually weak immediate roof. Reserves of the coal bed, which contains premium-quality metallurgical coal, are limited. Every effort is made to obtain maximum recovery rather than low mining costs at this mine.

The curves in figure 7 show the relation of tons of raw coal loaded per mobile loading unit per hour and per shift (8-hour) to thickness of coal bed (or mining height) at mines where pillars are extracted and at mines where pillars are not extracted. These curves show that less coal is loaded per hour or per shift in pillar extraction than in nonpillar extraction. This difference ranges from 2.0 tons per hour in 36 inches of coal to 2.5 tons per hour in 72 inches of coal and to 7.5 tons per hour in 120 inches of coal. The difference in tons per 8-hour shift is eight times that of tons per hour. The increasing difference in the thicker beds is the result of fewer delays caused by less roof-control work where pillars are not extracted. These delays have a greater effect upon the production of high-capacity loading machines used in thicker beds than upon lower-capacity machines in thinner beds because more tonnage is lost for each minute of delay. For example, production from a loading machine normally producing 12 tons per hour in thin coal will be cut to 10 tons because of an extra 10-minute delay in a 1-hour period. Production of a high-capacity loading machine, which normally produces 60 tons per hour in thick coal, would theoretically be diminished by 10 tons for a corresponding 10-minute delay.

The curve in figure 8 shows that the tons of raw coal loaded per conveyor per hour is directly proportional to thickness of coal bed at mines where pillars are extracted. Only a few conveyor operations where pillars were not extracted were studied, but the little information obtained indicates that the production per conveyor per hour is about the same whether pillars are extracted or not.

DESCRIPTION OF MINES

Mining at mines 56 to 67, inclusive, is described in this report. Operations at mines 1 to 55 are described in progress reports 1 to 5, inclusive. A summary of performance of mines 56 to 67 is given at the end of this report.

Mine 56

Mine 56, situated in west-central Pennsylvania, is opened by three drifts and four shafts. Mainline haulage is performed by a rope hoist operating in an 8,000-foot slope in the coal. This slope follows the 3-1/2 percent regional dip to the west. Empty mine cars and the hoisting rope are returned into the mine by a trolley locomotive. Two ventilating fans, operated exhausting, furnish about 215,000 cubic feet of air per minute circulated through 17 air splits in the mine.

The Lower Kittanning coal bed, which averages 39 inches thick in this area, is mined. The coal is overlain by 6 to 8 inches of bone coal, which is left in place to provide a firm roof. A firm dark shale averaging 8 feet thick, overlies the bone coal. This shale, which is absent in some areas, underlies a thick massive stratum of sandy shale. At present, the operating sections of the mine have an average cover of nearly 600 feet. The bottom is interbedded thin strata of fire clay, bone coal, and shale (see fig. 9).

Operations at this mine are completely mechanized, and 3,000 tons of raw coal are produced daily in three 8-hour shifts.

Mining Method

Mine 56 was opened in 1915, and hand loading was practiced until about 1930. All operations now are mechanized, and the room-and-pillar system of mining is followed and pillars are extracted.

The mine is developed by multiple main and panel entries, which are driven 16 to 18 feet wide on 60-foot centers. Main entries are driven in sets of five, with crosscuts on 80- to 90-foot centers. Panel entries, driven in pairs, are turned at right angles to the right and left off main entries (see fig. 10). Sixty-foot barrier pillars separate main entries from the first rooms in panels. Pillars between the first and second outby rooms in panels are left unmined to provide auxiliary main-return air courses after mining in the panels has been completed. Usually, one panel is mined at a time on each side of the main entries.

Five operating units are engaged in developing panels and pillar extraction in panels, five units in main-entry development, and two units in the extraction of

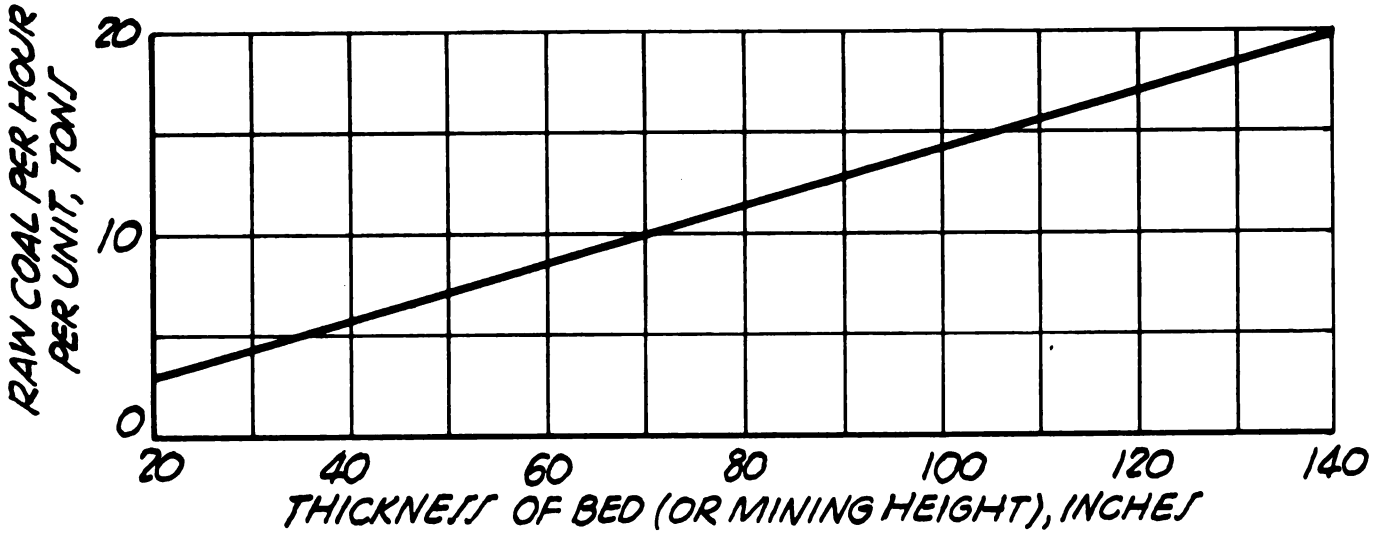


Figure 8. - Relation of raw coal loaded per conveyor unit per hour to thickness of coal bed (or mining height). Pillars extracted. (Tons per hour computed from full 7- ,8-, or 9-hour shifts.)

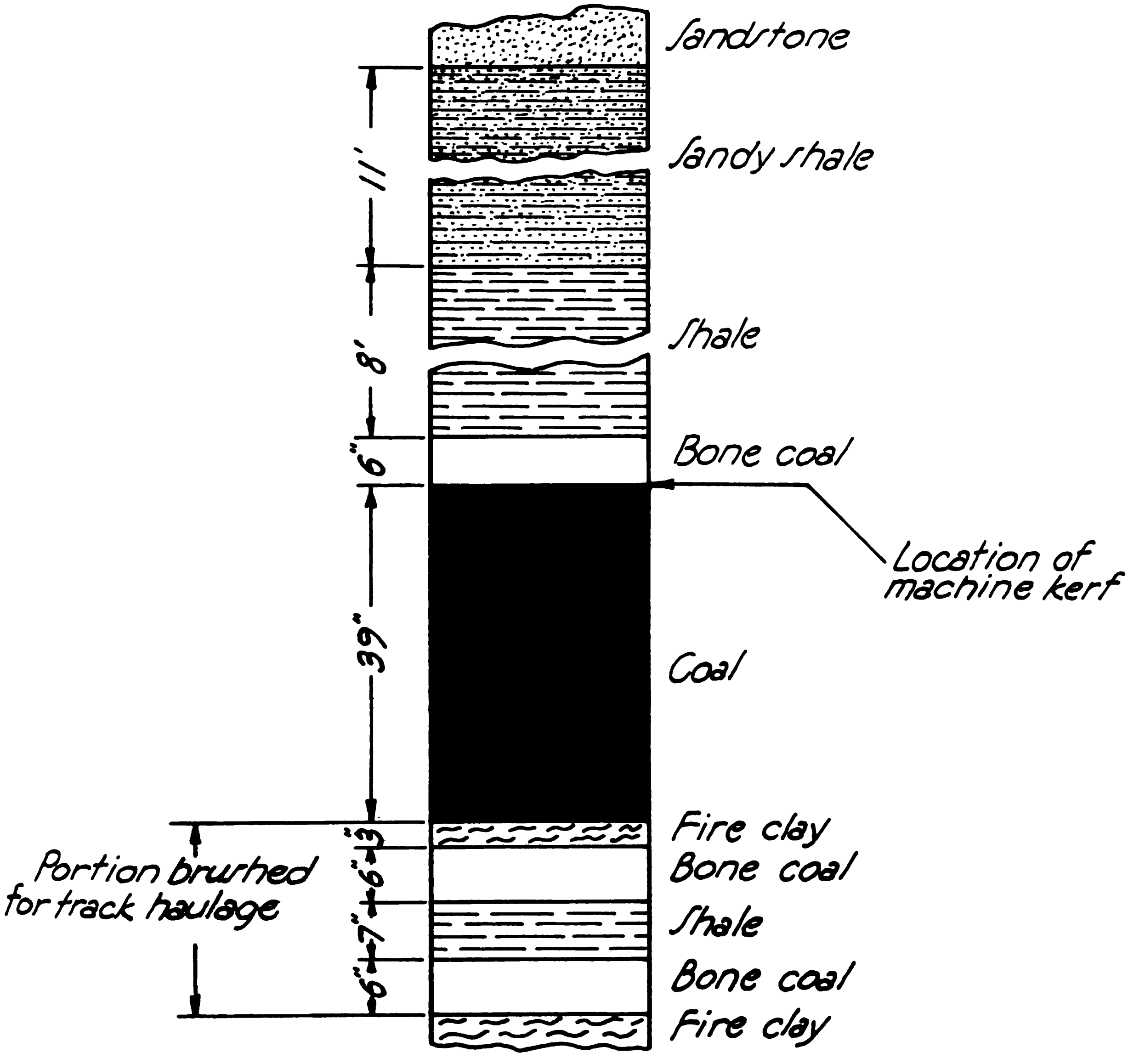


Figure 9. - Section of coal bed, roof and bottom rock at mine 56.

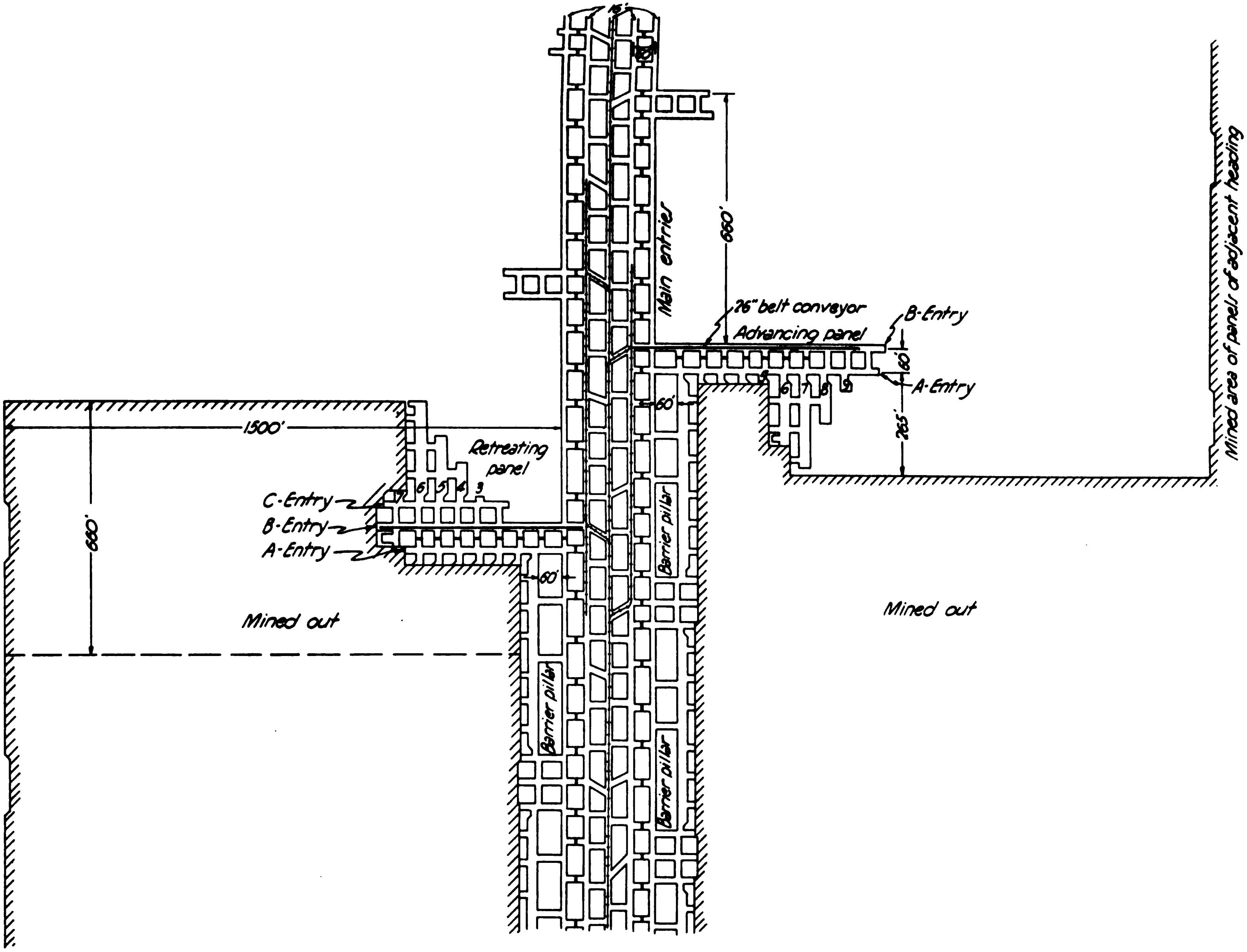


Figure 10. - Mining method at mine 56.

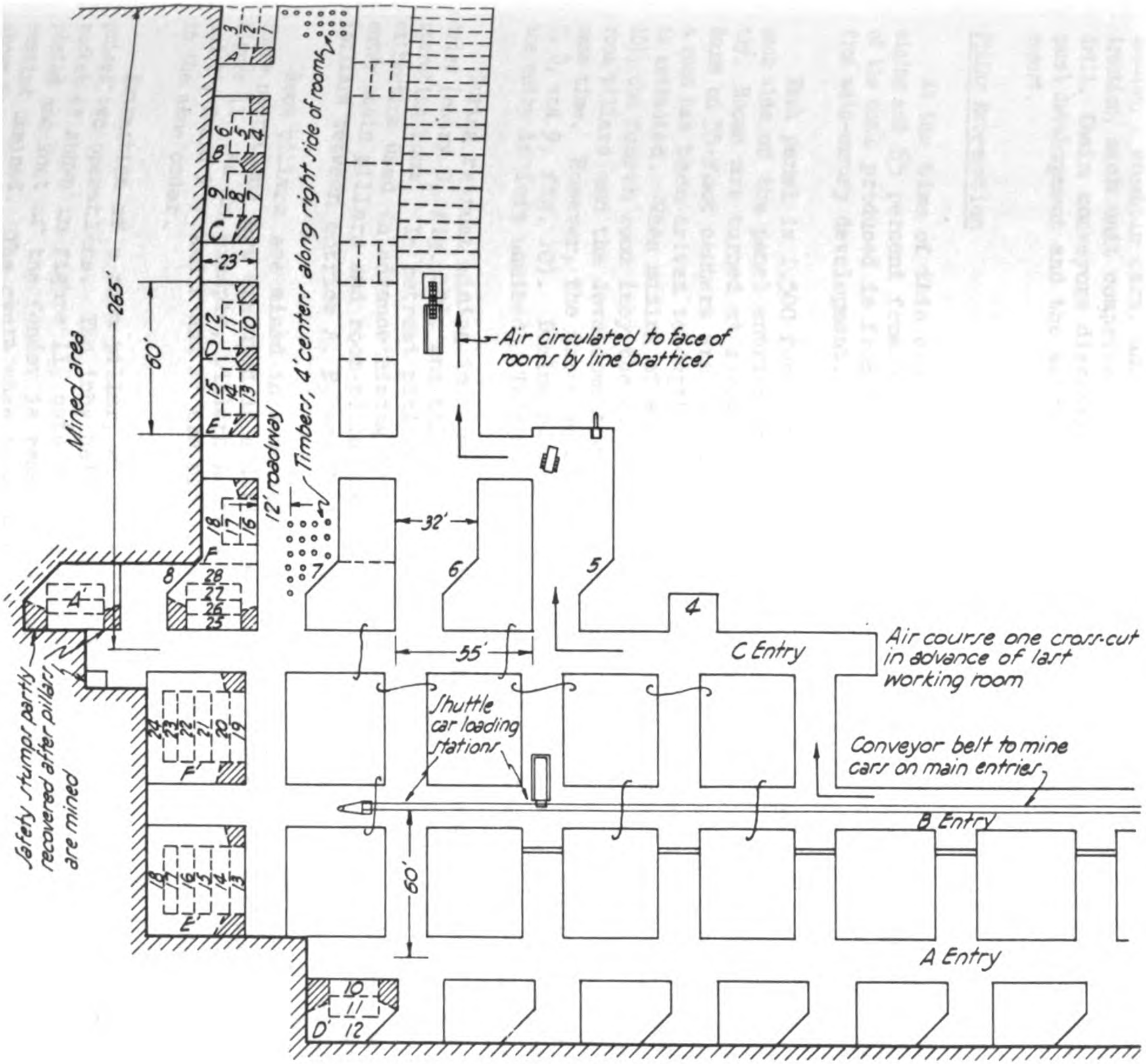

Mined area
265'
60'
23'
A
B
C
D
E
F
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
25
26
27
28
A'
8
12' roadway
Timbers, 4' centers along right side of rooms
Air circulated to face of rooms by line brattices
32'
7
6
5
4
55'
C Entry
Air course one cross-cut in advance of last working room
Shuttle car loading stations
Conveyor belt to mine cars on main entries
B Entry
60'
A Entry
Safety stumps partly recovered after pillars are mined
F'
19
20
21
22
23
24
E'
13
14
15
16
17
18
D'
10
11
12

Figure 11. - Pillar extraction at mine 56.

main-entry and barrier pillars. Each panel unit comprises 11 men, 1 mobile loading machine, 1 cutting machine, 1 drill, 2 shuttle cars, and 1 belt conveyor. Three entry development units employ 6 men, 1 mobile loading machine, 1 cutting machine, 1 drill, 1 shuttle car, and 1 belt conveyor; one unit uses 4 men, 1 chain conveyor, 1 cutting machine, and 1 drill; and one unit employs 5 men, 1 continuous mining machine, 2 shuttle cars, and 1 belt conveyor. In main-entry and barrier pillar extraction, each unit comprises 4 men, 1 chain conveyor, 1 cutting machine, and 1 drill. Chain conveyors discharge coal directly into mine cars. Only operations in panel development and the extraction of pillars in panels are discussed in this report.

Pillar Extraction

At the time of this study, about 35 percent of the coal produced was from pillar mining and 65 percent from entries, rooms, and crosscuts. However, about 70 percent of the coal produced is from pillar extraction and panel development and 30 percent from main-entry development.

Each panel is 1,500 feet long and 660 feet wide and comprises 25 to 27 rooms on each side of the panel entries and a 60-foot barrier pillar adjacent to the main entry. Rooms are turned at right angles off the outby entries as they are advanced. Rooms on 55-foot centers are driven 32 feet wide to a depth of 265 feet. As soon as a room has been driven to depth, the pillar between this room and the preceding room is extracted. When mining of a pillar is begun (pillar between rooms 5 and 6, fig. 10), the fourth room inby the pillar is turned (room 9, fig. 10). Mining one set of room pillars and the development of the next three inby rooms are carried on at the same time. However, the three rooms under development are at different depths (rooms 7, 8, and 9, fig. 10). During advance mining, about half of the room pillar next to the entry is left unmined. This pillar is recovered on retreat from the panel.

During retreat mining in a panel, a third entry is driven toward the main entries (entry C, fig. 10), and this entry is advanced one crosscut ahead of the last operating room. In retreat mining, the same method of room development and pillar extraction used in advance mining is followed. However, in retreat mining, the entry chain pillars and room-pillar stumps left in advance mining are extracted (pillars between entries A, B, and C, fig. 10, and room stumps adjacent to entry A).

Room pillars are mined in successive operations beginning with the inby pillar. These operations are executed in a definite order as illustrated alphabetically in figure 11. As an example, pillars A and A' are mined first. Then pillars B, C, D and D'; E and E'; and F and F' are mined. All room and entry pillars are extracted in the same order.

Extraction of a room pillar, which is about 60 feet long by 23 feet wide, comprises two operations. The inby half of the pillar is removed by first mining a pocket as shown in figure 11, cuts 4 and 5, pillar B. In cut 6, the pocket is completed and most of the fender is removed. A stump of coal less than 8 feet square remains unmined. The cycle then is repeated in the outby half of the pillar as shown by cuts 7, 8, and 9, pillar C. Thus, most of the two fenders are removed by cut 9, leaving two small stumps of coal. These stumps soon crush and usually part of this coal is recovered without cutting and blasting.

An operating unit in a pillar section comprises 11 men, 1 loading machine, 1 cutting machine, 1 drill, 2 shuttle cars, and 1 belt conveyor. The men are classified as follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Driller	1
Shuttle-car operators	2
Shot firer	1
Belt operator	1
Timberman	1
Foreman	1
Total	11

The cycle of operation in a pillar section follows:

1. Cut and set safety posts.
2. Drill.
3. Charge and blast.
4. Rock dust.
5. Extend line brattice.
6. Load coal and timber.

1. Cut and set safety posts. - The coal is top cut with shortwall machines equipped with 6-1/2-foot cutter bars. The cut is made in the top of the coal bed immediately below the bone-coal roof. Cutting machines are transported on crawler-mounted trucks. The two-man cutting crew also sets temporary safety posts, which are placed on 4-foot centers about 1 foot from the face.

2. Drill. - Four to seven holes, depending upon the width of the coal face, are drilled 6 feet deep near the bottom of the coal bed. The coal is drilled by one man with a hand-held electric auger-type drill.

3. Charge and blast. - Holes are charged with four cartridges of permissible explosive that is detonated electrically, one hole at a time. A certified shot firer is in charge of charging holes and blasting. An average of 4.25 tons of coal is produced per pound of explosive used.

4. Rock dust. - Working places are rock dusted by hand immediately after the coal is blasted.

5. Extend line brattice. - Air is circulated to the working face by means of a line brattice that is secured to a row of posts and extended after the coal has been blasted. This work and rock dusting are performed by the timberman.

6. Load coal and timber. - Coal is loaded into 3-1/2-ton cable-reel shuttle cars with crawler-mounted mobile loading machines. The crew comprises an operator and helper. The helper places permanent props, which are installed on 4-foot centers, during the time the loading machine is cleaning up the fall of coal.

Shuttle cars transport the coal to the panel entries and discharge it onto 26-inch belt conveyors. These belts discharge the coal into 4-ton mine cars at a loading station on the main entry. Mine cars are spotted for loading with an electric motor-driven car hoist. Loaded trips are transported to the main slope by trolley locomotives. Mainline motor haulageways are bottom-brushed to provide a minimum clearance of 5 feet above the rail.

Roof Action

All rooms are timbered systematically with posts set on 4-foot centers in rows 4 feet apart to within 1 foot of the face. A 12-foot roadway is left on the left side of the room. The same system of timbering is used in all pillar mining. Where necessary, crossbars are used on haulageways. Posts are not recovered and are allowed to break as the bottom heaves and roof subsides after pillars have been removed. One row of posts is set along each side of the conveyor belt in panel entries.

The roof is bone coal, which is overlain by thick beds of firm shale and sandstone (see fig. 9). This roof does not break immediately after pillars are removed. The thinner and softer bottom beds heave as the pillars are drawn, and this action breaks the props in the mined area permitting the roof to cave after large areas have been mined.

Owing to the roof and bottom action, the mining system is planned to keep pillar mining concentrated and a minimum area opened by room development in advance of pillar mining. This system requires continuous operation so that the rate of retreat is fast enough to keep ahead of bottom heaving. This is necessary to maintain enough height for movement of equipment and to avoid effects of squeezes that often develop during intermittent operation.

Each unit foreman is responsible for maintaining the proper mining sequence and for all mining operations in his section.

Recovery

An average of 96,000 tons of raw coal is recovered from a standard-size panel, which includes the 60-foot barrier pillars along the main entry. These pillars are not mined with the pillars in the panel. Based upon this production and the area in a panel, the average recovery in panels is estimated at 85 percent.

Most of the main-entry barrier pillars and chain pillars are recovered on retreat from a mined-out area. Over-all mine recovery, estimated from areas in which mining has been completed, is about 75 percent.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	9	9	2	20
Loading-machine helpers	4	4	2	10
Cutting-machine operators	9	9	2	20
Cutting-machine helpers	9	9	2	20
Drillers	9	9	2	20
Shuttle-car operators	13	13	4	30
Shot firers	9	9	2	20
Belt operators	7	7	2	16
Section foremen	9	9	2	20
Mechanics	6	5	1	12
Conveyor men	12	12	-	24
Conveyor foremen	1	1	-	2
Total	97	96	21	214

Classification	Shift			Total
	1st	2d	3d	
Other underground employees:				
Motormen	19	7	2	28
Motor bosses (dispatchers)	1	1	-	2
Trackmen	9	3	-	12
Drainage men	3	2	1	6
Ventilation men	3	1	-	4
Timbermen	3	1	-	4
Clean-up men (rock)	13	6	4	23
Wiremen	3	1	-	4
Mechanics	9	3	-	12
Fire bosses	2	1	-	3
Assistant foremen	6	5	1	12
Total	71	31	8	110
Total underground employees	168	127	29	324
Surface employees:				
Hoisting engineers	1	1	-	2
Weighmen	2	1	-	3
Dumpers and helpers	2	2	-	4
Railroad-car shifters and helpers	8	4	-	12
Car couplers	2	2	-	4
Dirt pickers	2	2	-	4
Cleaning plant men	4	3	-	7
Cleaning plant foremen	1	1	-	2
Repairmen	7	4	2	13
Car repairmen	5	1	-	6
Blacksmiths	2	-	-	2
Lampmen	1	1	-	2
Watchman	-	-	1	1
Tipple foremen	1	1	-	2
Carpenters	8	-	-	8
Carpenters' foreman	1	-	-	1
Total	47	23	3	73
Supervisory employees:				
Superintendent	1	-	-	1
Mine foreman	1	-	-	1
Engineer	1	-	-	1
Master mechanic	1	-	-	1
Mine clerks	2	-	-	2
Shop foremen	1	1	-	2
Total	7	1	-	8
Total employees	222	151	32	405

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons	3,000
Average daily production, raw coal, in panels, tons	2,100
Average number shifts per day, mechanized units, in panels	10
Average production per unit-shift, panels, tons	210

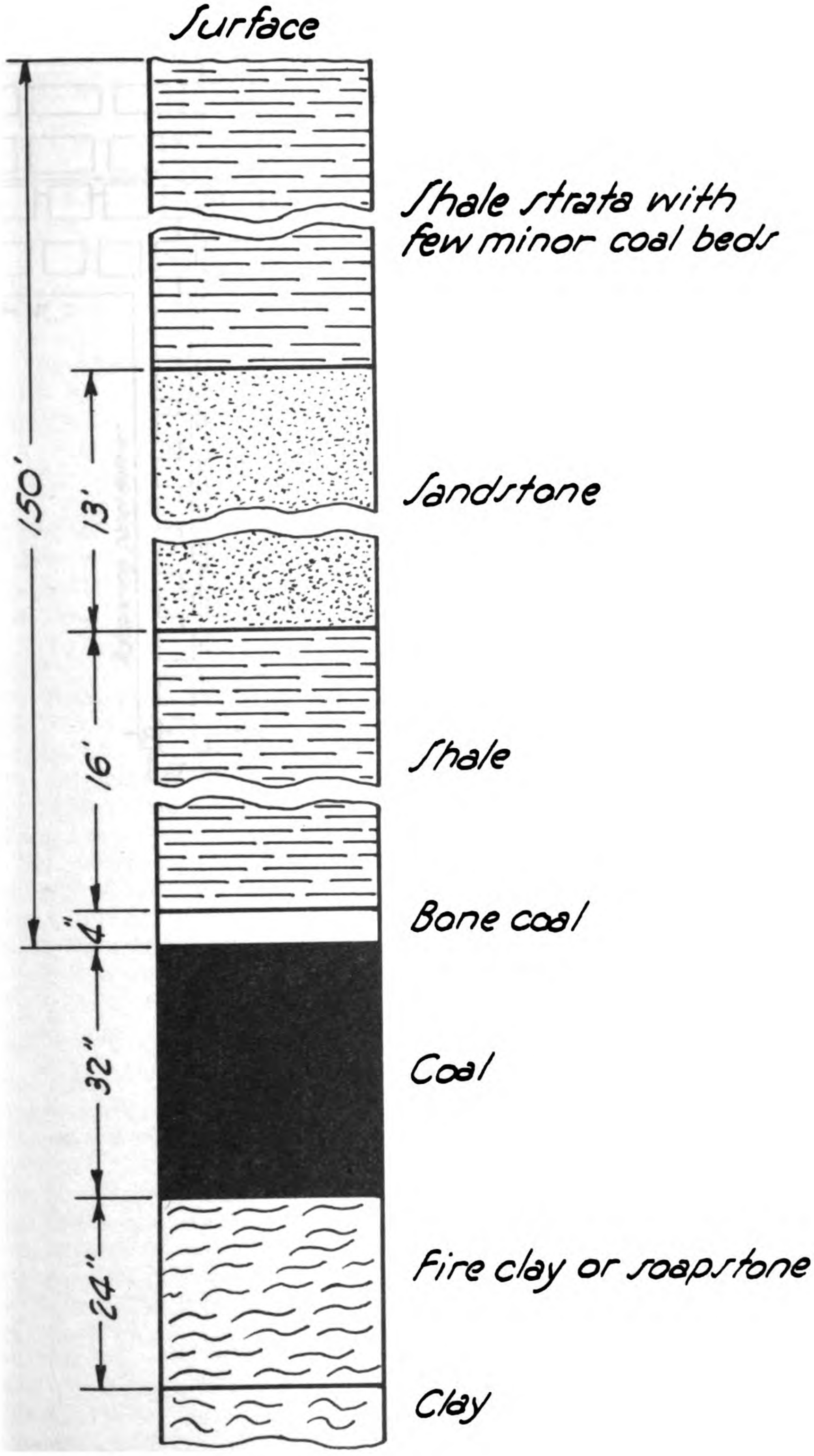


Figure 12. - Section of coal bed, overburden, and bottom rock at mine 57.

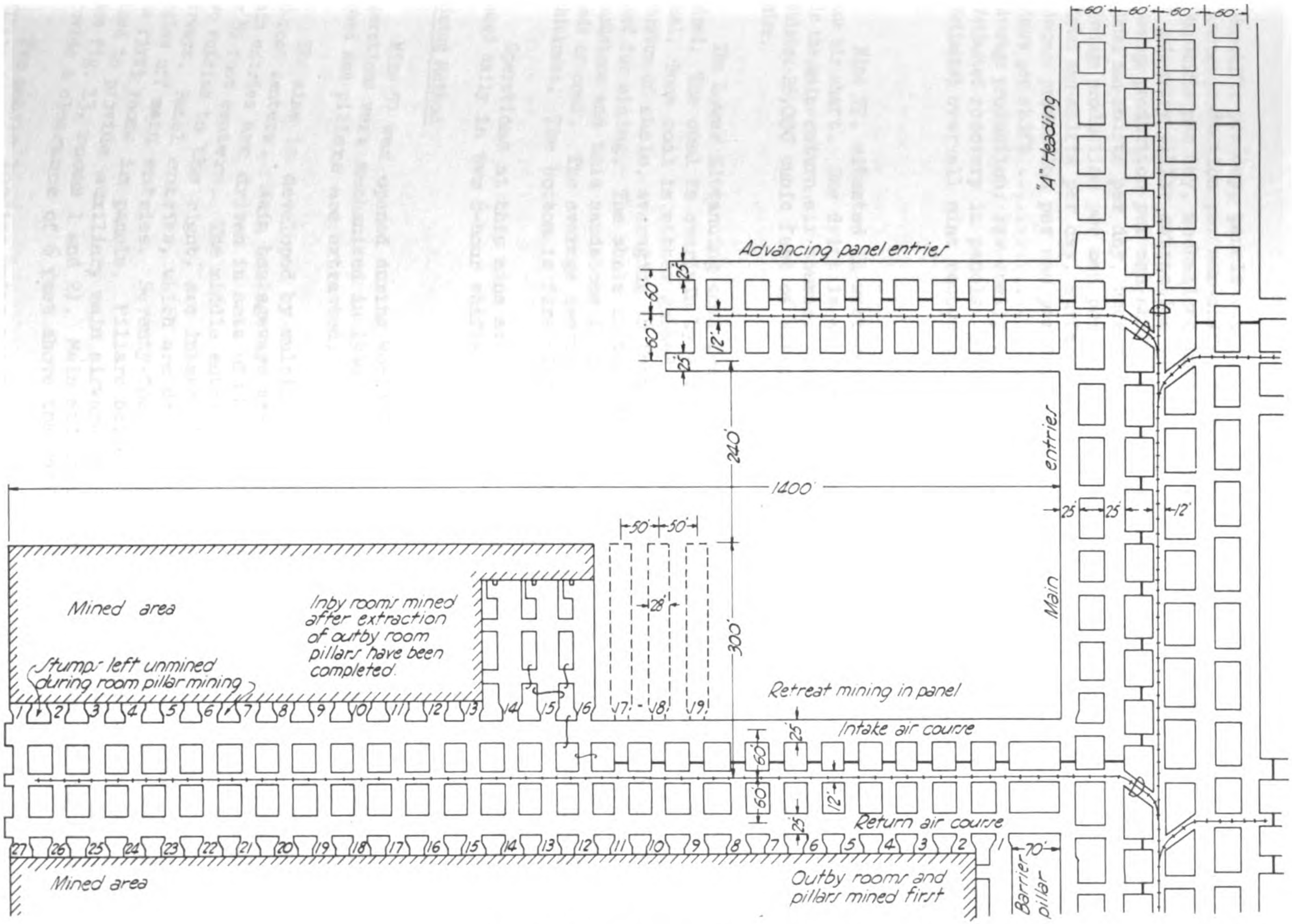


Figure 13. - Mining method at mine 57.

Man-shifts per day, panels	110
Average production per man-shift, panels, tons	19.1
Man-shifts per day, mechanized units, in panels, entry development, and main-entry pillar extraction	214
Average production per man-shift, mechanized units, tons	14.0
Total man-shifts per day, underground	324
Average production per man per day, underground, tons	9.3
Total man-shifts per day, surface and underground	405
Average production per man per day, tons	7.4
Hours per shift	8
Average production, raw coal, per pound of explosive, tons	4.25
Estimated recovery in panels, percent	85
Estimated over-all mine recovery, percent	75

Mine 57

Mine 57, situated in west-central Pennsylvania, is opened by two drifts and one air shaft. One drift is an intake airway and main haulageway; the other drift is the main-return air course. The ventilating fan is operated exhausting and circulates 26,000 cubic feet of air per minute in one continuous circuit through the mine.

The Lower Kittanning coal bed, which averages 32 inches thick in this area, is mined. The coal is overlain by 4 inches of bone coal that falls with each cut of coal. Bone coal is either gobbed in the mine or hand-picked at the tipple. A firm stratum of shale, averaging 16 feet thick, overlies the bone coal and provides a good roof for mining. The shale in most areas is overlain by a 12- to 14-foot stratum of sandstone and this sandstone is overlain by shale strata that contains several thin beds of coal. The average overburden in working sections of the mine is 150 feet in thickness. The bottom is fire clay or soapstone (see fig. 12).

Operations at this mine are completely mechanized, and 600 tons of coal are produced daily in two 8-hour shifts.

Mining Method

Mine 57 was opened during World War I, and hand-loading was practiced until operations were mechanized in 1946. The room-and-pillar system of mining is followed and pillars are extracted.

The mine is developed by multiple main and panel entries, which are driven on 60-foot centers. Main haulageways are 12 feet wide and air courses 25 feet wide. Main entries are driven in sets of five, with crosscuts turned at right angles on 70- or 80-foot centers. The middle entry, which is equipped for track haulage, and the two entries to the right, are intake airways; the two entries to the left are return airways. Panel entries, which are driven in sets of three, are turned at right angles off main entries. Seventy-foot barrier pillars separate main entries from the first rooms in panels. Pillars between the first and second rooms are left unmined to provide auxiliary main airways after mining in the panel has been completed (see fig. 13, rooms 1 and 2). Main and panel entry haulageways are top brushed to provide a clearance of 6 feet above the rail.

Two mobile loading units are engaged in developing panels and extracting room pillars in panels, one mobile loading unit in main entry development, and two conveyor units in the extraction of panel entry chain pillars. Each mobile loading unit comprises seven men, one cutting machine, one drill, one mobile loading machine, and an assembly of four to seven chain conveyors. Each conveyor unit comprises three men, one cutting machine, one drill, and one shaking conveyor. Only operations in panel development and extraction of room pillars in panels are discussed in this report.

Pillar Extraction

At the time of this study, about 70 percent of the coal produced was from pillar extraction and panel development and 30 percent from main entry development.

Panels average 1,400 feet long and 600 feet wide and each comprises 27 rooms on each side of the panel entries and a 70-foot barrier pillar adjacent to the main entry. A set of panel entries is developed before rooms are turned. Rooms are turned at right angles off the airway entries and are driven 28 feet wide on 50-foot centers to a depth of 240 feet. Rooms are driven to this depth because room conveyors, when fully extended, are 300 feet long. The outby rooms are mined first, beginning at the outby end of the panel and advanced as shown by room numbers in figure 13. Inby rooms are mined then, beginning at the inby end of the panel and retreating toward the main entries. A set of three rooms is driven at a time. After three rooms are developed, the pillars between them are extracted before the next three rooms are developed. Thus, three room conveyors and one entry conveyor are required for extraction of room pillars (see fig. 14).

Room pillars, which are 50 feet long and 22 feet wide, are extracted in successive operations, beginning with each of the inby pillars. These operations are executed in a definite order, as shown alphabetically in figure 14. For example, inby halves of pillars A, B, and C are mined first, as shown by the cutting sequence. Then the outby halves of these three pillars are extracted. Following the complete removal of pillars A, B, and C, pillars D, E, and F are mined. All room pillars are extracted in the same order, and the cave-line of three retreating rooms is parallel to the panel entries.

The inby halves of three pillars are removed by first mining small pockets (see fig. 14, cuts 1, 2, and 3, pillars A, B, and C). Cuts 4, 5, and 6 and 7, 8, and 9 follow to complete the operation. A stump of coal 6 feet square remains, but this stump is later drilled and blasted and often partly recovered. The cycle is then repeated in the outby halves of the pillars as shown in figure 14, cuts 10 to 18. The outby half of room pillars next to the entry is left unmined during extraction of room pillars. These pillars and entry chain pillars are recovered after all room pillars in the panel have been extracted. An operating unit using shaking conveyors is employed for this work.

A mobile loading unit crew in a pillar section follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator and driller	1
Cutting-machine helper and driller	1
Shot firer	1
Timberman	1
Conveyor and hoist operator	1
Total	7

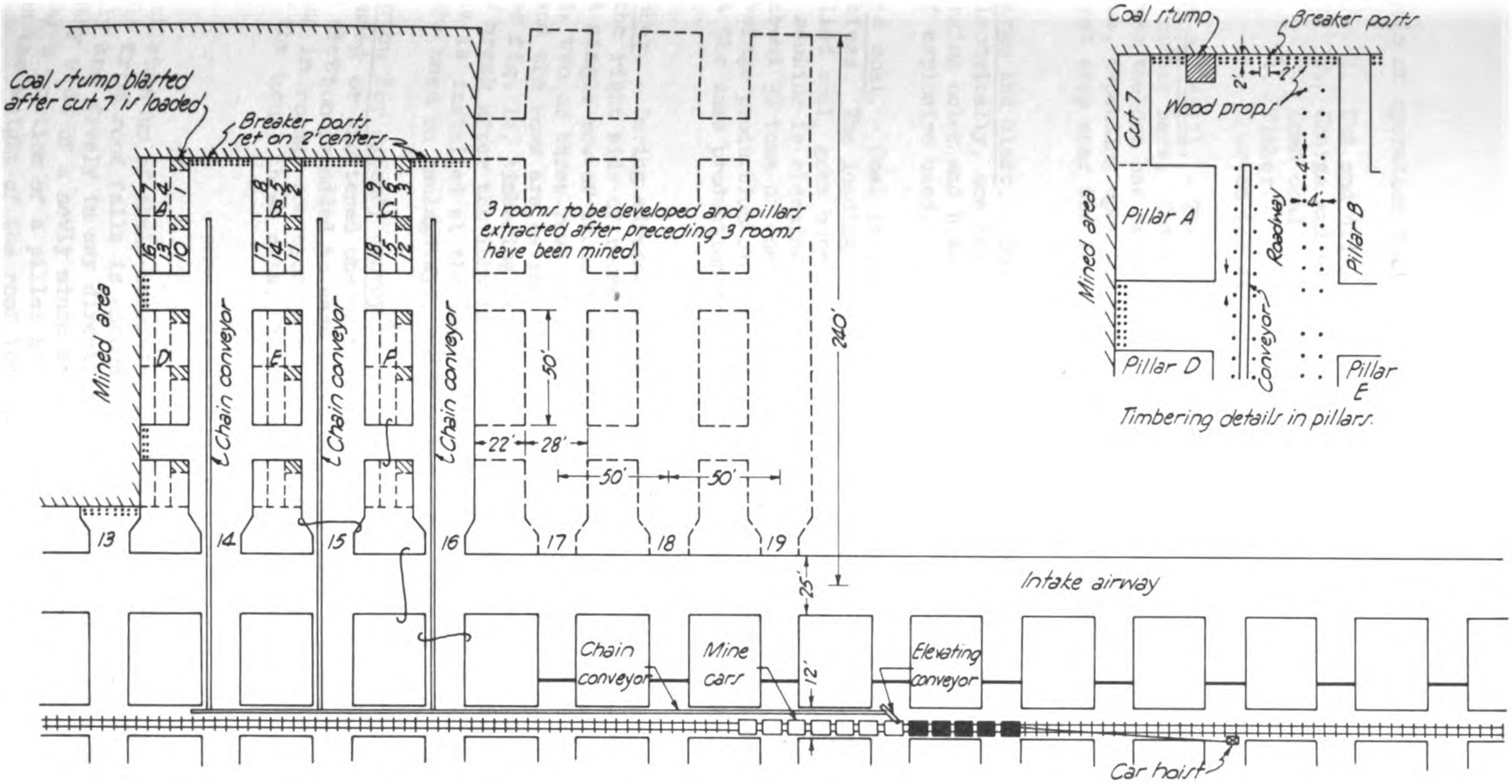


Figure 14. - Pillar extraction at mine 57.

The cycle of operation follows:

1. Cut and drill.
2. Charge and blast.
3. Load coal.
4. Timber.
5. Shorten (or extend) conveyors.

1. Cut and drill. - The coal is bottom-cut with shortwall machines equipped with 7-foot cutter bars. Cutting machines are transported on crawler-mounted trucks. After the cut has been made, the two-man cutting crew also drills three or four holes, depending upon the width of the working face. These holes are drilled 6 feet deep near the top of the coal bed with hand-held electric auger-type drills.

2. Charge and blast. - Holes are charged with permissible explosive that is detonated electrically, one hole at a time. A certified shot firer performs the work of charging holes and blasting. An average of 11.0 tons of coal is produced per pound of explosive used.

3. Load coal. - Coal is loaded onto chain conveyors with crawler-mounted mobile loading machines. The loading crew comprises an operator and helper. The helper shovels spilled coal, gobs bone coal, and sets temporary safety posts during the time the loading machine is cleaning up the fall of coal. During room development, the crew loads about 30 tons of coal per shift more than during pillar extraction. However, the average production over an extended period of time is about 90 tons per shift, about the same production that is obtained by mobile loading units in entry development.

4. Timber. - During advance mining, two rows of props are set on 4-foot centers along the right side of rooms and air course entries to within about 5 feet of the face. A single row of props is set on each side of chain conveyors. During retreat mining, two or three rows of breaker posts are set on 2-foot centers across the rooms, and the rows are extended along the inby ends of cuts in pillars as they are made (see fig. 14, timbering details). These props are not recovered but are permitted to break after the inby half of the pillar has been mined. A new set of breaker posts is installed at the inby end of the remaining half of the pillar. Crossbars are used on haulageways, where necessary.

5. Shorten (or extend) conveyors. - Conveyors are assembled in 6-foot sections and are extended or shortened one or more sections at a time as needed. During room advance, one section is added to each conveyor after each cut has been loaded. During retreat mining in rooms, conveyors are shortened after a portion of a pillar has been extracted by the usual three cuts. This work is performed by the timberman and shot firer.

Roof Action

The thick stratum of shale overlying the bone coal provides a good roof, and little trouble from roof falls is encountered in advance mining. However, the shale breaks readily and freely in any direction after breaker posts have been installed along the outby side of a newly mined area. The overburden subsides slowly but steadily after a portion of a pillar has been extracted. The breaker posts bend and soon break as the weight of the roof increases. The roof over the newly mined area is then supported at the outby end by coal pillars and breaker posts. Under the cantilever action produced, the roof breaks at the new breaker posts and caves in a straight line parallel to the entries across three rooms. Caves were observed to be high and apparently include the stratum of sandstone overlying the immediate shale roof. Bottom heaving often occurs when working places in pillars are permitted to stand idle for an extended period of time. If parts of pillars remain unmined because of premature falls, the weight of the roof is carried over to unmined pillars and squeezes result. Under the present system of mining, only three rooms are open at a time, and the small number of working places requires rapid retreat during pillar extraction.

Recovery

In a standard-size panel, about 65 percent of the coal is mined from entries, rooms, and crosscuts, and 35 percent from pillars. It is estimated by the company that 90 percent of the coal in those pillars mined is recovered. However, barrier pillars adjoining main entries and the room pillars between the first and second outby rooms are not mined with the panels. Therefore, including these pillars in the panel area, recovery in panels is estimated at 85 percent.

At the time of this study, the extraction of panel entry chain pillars and room stumps was lagging. Some panel entries were being maintained and used as drainageways and short-cut haulageways. Also, the present system of mining has been in effect for only a short time. These factors make it impossible to arrive at an estimate of over-all mine recovery under present mining methods.

Classification of Employees

Classification	Shift		Total
	1st	2d	
Mechanized units:			
Loading-machine operators	3	3	6
Loading-machine helpers	3	3	6
Cutting-machine operators and drillers	3	3	6
Cutting-machine helpers and drillers	3	3	6
Shot firers	3	3	6
Timbermen	3	3	6
Conveyor and hoist operators	3	3	6
Conveyor men (hand-loaded conveyors)	6	6	12
Foremen	1	1	2
Total	28	28	56
Other underground employees:			
Motormen	2	2	4
Brakemen	1	1	2
Ventilation man	1	-	1
Trackmen	2	-	2
Timberman	1	-	1
Repairman	1	-	1
Greaser	1	-	1
Foremen	1	1	2
Total	10	4	14
Total underground employees	38	32	70

Classification	Shift		Total
	1st	2d	
Surface employees:			
Dumpers and helpers	3	2	5
Dirt pickers	1	1	2
Cleaning plant operator	1	-	1
Mechanic	1	-	1
Total	6	3	9
Supervisory employees:			
Superintendent	1	-	1
Storeroom clerk	1	-	1
Office clerk	1	-	1
Total	3	-	3
Total employees	47	35	82

Summary

Percent of mine mechanized	100
Average daily production, raw coal, tons	600
Average daily production, mobile units in panels, raw coal, tons	360
Average daily production, mobile units, panels and entry development, raw coal, tons	540
Average daily production, conveyor units, raw coal, tons	60
Average number man-shifts per day, mobile units in panels	28
Average daily production per man-shift, mobile units in panels, raw coal, tons	12.9
Average number man-shifts per day, mobile units, panels and entry development.	42
Average daily production per man-shift, mobile units, panels and entry development, raw coal, tons	12.9
Average number man-shifts per day, conveyor units	12
Average production, conveyor units, raw coal, tons	5.0
Man-shifts per day, mechanized units, panels, entry development, and entry pillar extraction	56
Average production per man-shift, mechanized units, tons	10.7
Total man-shifts per day, underground	70
Average production per man per day, underground, tons	8.6
Total man-shifts per day, surface and underground	82
Average production per man per day, tons	7.3
Hours per shift	8
Average production, raw coal, per pound of explosives, tons	11.0
Estimated recovery in panels, percent	85

Mine 58

Mine 58, situated in western Pennsylvania, is opened by two haulage drifts and an air course drift. The two haulage drifts are intake airways; one is used for transporting loaded trips of coal and one for returning empty trips. The ventilating fan is operated exhausting and circulates 40,000 cubic feet of air per minute in two air splits in the mine.

The Upper Freeport bed, which averages 63 inches thick in this area, is mined. Two shale partings, each about 3 inches thick, occur 6 inches and 26 inches above the bottom of the bed. The portion of the bed mined comprises the two upper benches of coal and the upper parting. The lower parting and the 6-inch lower coal bench are not mined (see fig. 15). The coal is overlain by 6 inches of bone coal that falls with each cut and is loaded with the raw coal. A 3-cell Baum-type jig washing plant is used to remove shale, bone coal, and other impurities. A hard, massive stratum of shale, ranging from a few inches to over 8 feet thick, overlies the bone coal in some areas. This shale is overlain by a thick stratum of sandstone. In some areas, the shale is absent, and the bed is immediately overlain by sandstone. The overburden in operating sections of the mine averages 200 feet thick. Gentle dips and rolls occur locally in the mine, but the coal bed generally is flat lying.

Operations at this mine are completely mechanized, and an average of 1,821 tons of clean coal is produced daily in two 8-hour shifts. Average daily production of raw coal is estimated at 2,017 tons.

Mining Method

Mine 58 was opened before World War I, and hand loading was practiced until operations were mechanized in November 1945. The room-and-pillar system of mining is followed and pillars are extracted.

The mine is developed by multiple main and panel entries, which are driven 15 feet wide. Main entries are driven in sets of four on 75-foot centers with crosscuts turned 60 degrees from the haulage entry on 75- to 100-foot centers. Panel entries are driven in sets of three on 60-foot centers and are turned to the right and left off the main entries. Main entries are separated from rooms in panels by 250-foot barrier pillars (see fig. 16).

Three mechanized units are engaged in pillar extraction in one panel and a fourth unit in panel entry development. At the time of this study, main entry development was well advanced and had been temporarily suspended.

Pillar Extraction

At the time of this study, about 80 percent of the coal produced was from room development and pillar extraction in panels and 20 percent from panel entry development.

Panels, including 250-foot barrier pillars along the main entries, average 2,000 feet long and 620 feet wide. Each panel comprises about 30 rooms turned at right angles off each side of the panel entries during retreat mining. Rooms are turned on 60-foot centers and are driven 20 feet wide to a depth of 250 feet. Room crosscuts, 20 feet wide, are turned at right angles on 60-foot centers. Four rooms are always under development on each side of the panel entries and are at different depths (rooms 21, 22, 23, and 24, fig. 16). During the development of these rooms, pillars in the four preceding rooms and the panel entries are extracted (pillars A to J, fig. 16). These pillars are extracted to form cave lines 45 degrees to the entries. After pillars A to J have been extracted, development of rooms 21 has been completed. Then, mining of pillars A-1 to J-1 and development of rooms 25 are begun.

Each of the three units working in a panel is assigned its division of the work. For example, unit I is assigned to the development of the four rooms on the right side of the panel and to the extraction of pillars H, I, and J; unit II to the development of four rooms on the other side of the panel and extraction of pillars A, B, and C; and unit III to the extraction of pillars D, E, F, and G. Unit III is

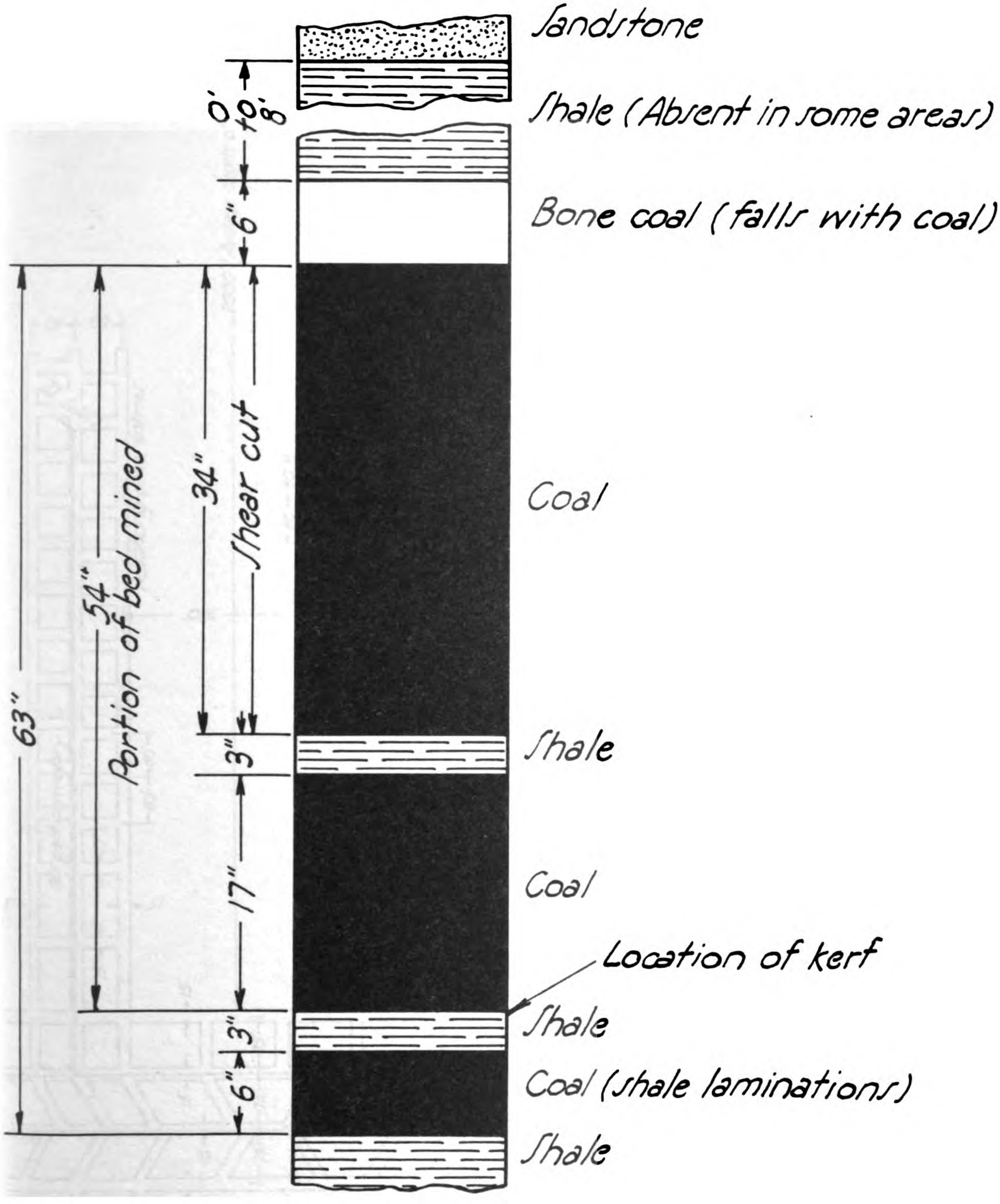


Figure 15. - Section of coal bed, roof, and bottom rock at mine 58.

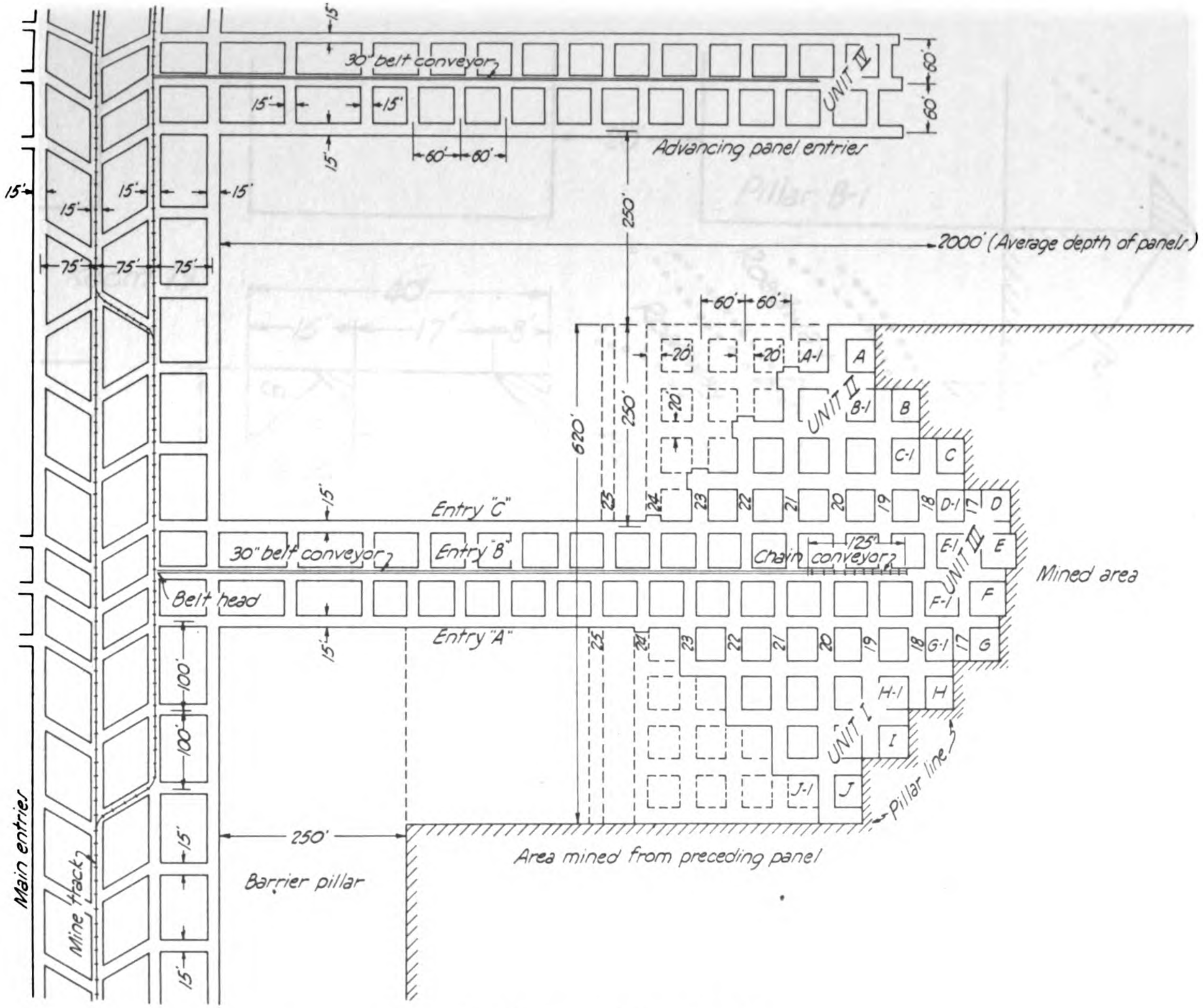


Figure 16. - Mining method at mine 58.

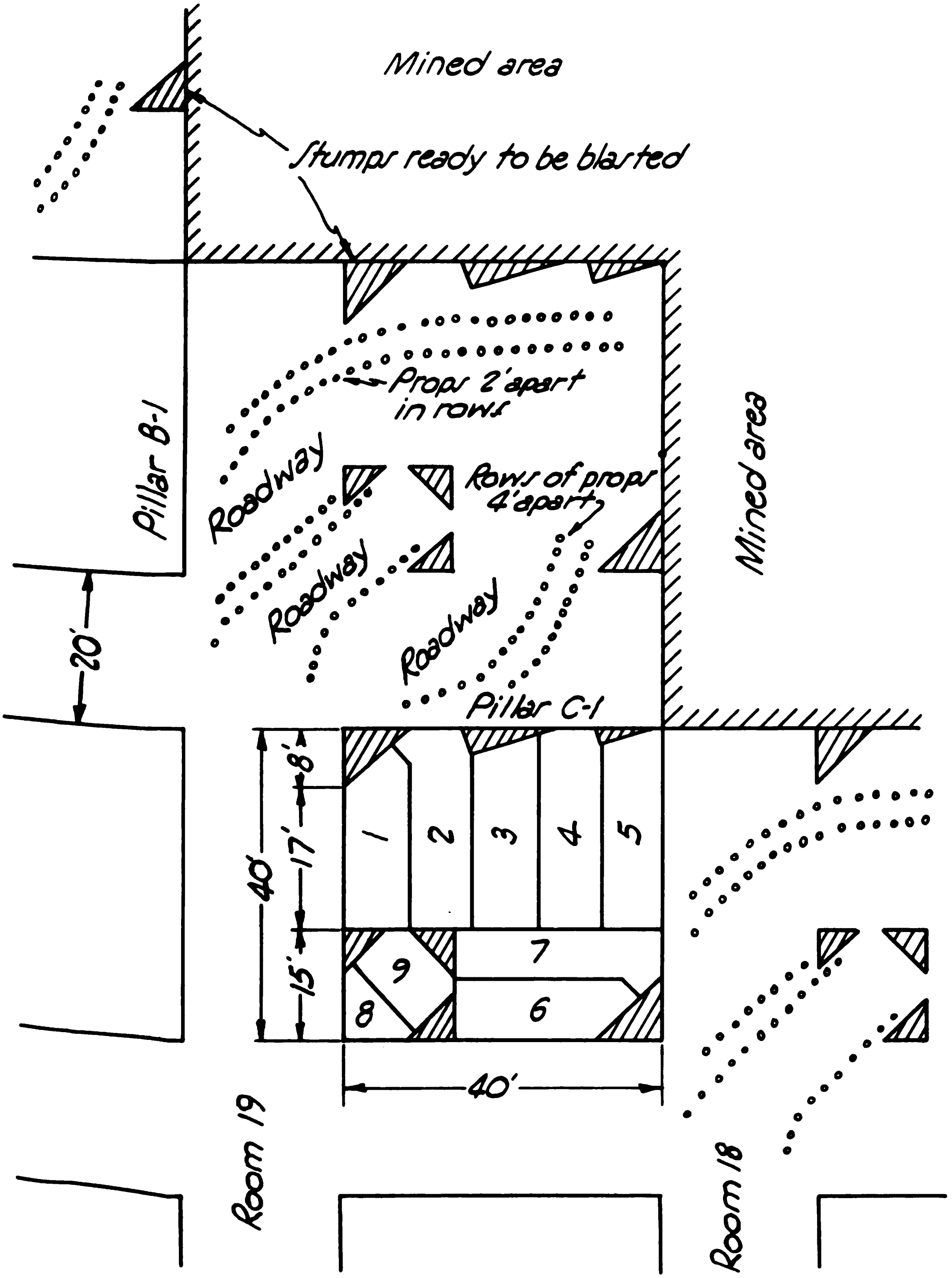


Figure 17. - Pillar extraction and timbering at mine 58.

assigned less work and, therefore, often mines some of the pillars assigned to the other two units. Unit operation is regulated to keep the pillar line in balance at all times. Shuttle cars assigned to units I and II discharge onto the chain conveyor from crosscuts along the side of the conveyor. Shuttle cars in unit III discharge onto the chain conveyor at the inby end of the conveyor. When the pillar line reaches the first crosscut inby the chain conveyor, the conveyor belt is shortened and the chain conveyor is moved about 150 feet outby the pillar line.

Pillars comprise blocks of coal about 40 feet square. The method of extraction generally practiced is shown by the cutting sequence in pillar C-1, figure 17. Over half the pillar is removed by pockets cut from the room side of the pillar (cuts 1 to 5). The fender next to the gob is cut through every alternate cut, and a similar pocket is mined from the outby crosscut side of the pillar (cuts 6 and 7). The small block of coal remaining is then mined (cuts 8 and 9), the large triangular stumps are blasted, and the roof over the mined area crushes the small fenders, breaks the props, and caves.

A unit in a pillar section comprises 11 men, 1 rubber-tired universal-type cutting machine, 1 hand-held electric auger-type drill, 1 crawler-mounted mobile loading machine, and 2 cable-reel shuttle cars. The men are classified as follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator and driller	1
Cutting-machine helper and driller	1
Shuttle-car operators	2
Timbermen	2
Shot firer	1
Belt operator	1
Foreman	1
Total	11

The cycle of operation in a pillar section follows:

1. Timber.
2. Cut and drill.
3. Charge and blast.
4. Load coal.

1. *Timber*. - A timbering crew of two men is a part of each operating unit. A row of props is set on 3- or 4-foot centers along the right rib of rooms as they are advanced. Two rows of props on 2-foot centers are set on the inby side of shuttle car roadways at and near working faces in pillars (see timbering detail, fig. 17). Timbers are not recovered and are allowed to break as caving occurs. Crossbars are used on haulageways, where necessary.

2. *Cut and drill*. - The coal is bottom cut and sheared with rubber-tired universal-type cutting machines equipped with 9-foot cutter bars. The shear is placed 5 feet from the inby rib and extends from the roof to the upper shale parting. Three or four holes are drilled near the top of the coal face. The hole next to the shear cut on the wide side is angled toward this cut. Two snubber or breaker holes, 10 feet apart, are drilled on each side of the shear cut, just above the shale parting. These holes are angled toward the shear cut. Drilling is done with hand-held electric auger-type drills. The power cables for these drills are plugged into receptacles on the cutting machines. A crew of two men cuts and drills 10 to 12 coal faces per shift.

3. Charge and blast. - Top holes are charged with four or five cartridges of permissible explosive and snubber holes with one or two cartridges. The explosive is detonated electrically, one hole at a time. The charges in the snubber holes are detonated first, the center top holes second, and corner top holes last. A certified shot firer does the charging and blasting. An average of 5 tons of raw coal is produced per pound of explosive used. Fresh falls of coal are sprinkled with water to allay dust. This work also is done by the shot firer.

4. Load coal. - Coal is loaded into 4-ton shuttle cars with crawler-mounted mobile loading machines. One loading unit loads 10 to 12 cuts per shift. The average production per mechanized unit per shift in the retreating panel is 260 tons of raw coal. The loading crew comprises an operator and helper.

Two shuttle cars are used in each unit and these cars transport the coal by separate routes to a chain conveyor, which is a feeder to a 30-inch belt conveyor. The gathering belt conveyor discharges the coal into 4-1/2-ton mine cars at a loading station on the main entries. Mine cars are spotted for loading with electrically driven hoists. Loaded trips are transported to the tipple by trolley locomotives.

Roof Action

The shale and sandstone roof strata break readily after coal stumps have been blasted. The props bend and soon break under the increased roof pressure. The cave line then advances to the solid pillars of coal. The direction of the break line is not important as the roof rock shears readily in any direction. Caves are high and apparently closed, as little or no evidence of subsidence can be seen on the surface. Bottom heaving and squeezing do not occur in this mine.

Roof is controlled by maintaining short pillar lines. Systematic timbering and small stumps that are left in each pillar afford enough support to hold the roof until the last cut of coal has been loaded. The coal in this bed is friable. After the larger stumps have been blasted, the smaller fenders crush and the props fail. The overlying roof then breaks and falls.

Recovery

The coal bed in this area occurs in three benches, which have a total coal thickness of 57 inches (see fig. 15). The 6 inches of bone coal roof is of such poor quality that it cannot be classified coal. The lower 6 inches of the coal bed, which is laminated coal and shale, is not mined because this bench of coal is high in ash and sulfur. Therefore, about 90 percent of the total coal section is mined. Average recovery from the portion of the bed mined in standard-size panels, which include the 250-foot barrier pillars along the main entries, is estimated at 84 percent. Average panel recovery, considering the total thickness of coal in the bed, is about 75 percent because the 6-inch bottom bench of coal is not mined. The present method of pillar extraction has improved over-all recovery at this mine. However, the method has not been in effect long enough to provide enough data to compute over-all percentage of recovery.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	4	4	-	8
Loading-machine helpers	4	4	-	8
Cutting-machine operators	4	4	-	8
Cutting-machine helpers	4	4	-	8
Shot firers	4	4	-	8
Timbermen	8	8	-	16
Foremen	4	4	-	8
Shuttle-car operators	8	8	-	16
Belt operators	4	4	-	8
Total	44	44	-	88
Other underground employees:				
Motormen	2	2	2	6
Snappers	2	2	-	4
Trackmen	2	2	5	9
Wiremen	-	-	4	4
Mechanics	2	1	4	7
Mechanics' helpers	3	1	4	8
Laborers	-	-	2	2
Foremen	1	1	3	5
Total	12	9	24	45
Total underground employees	56	53	24	133
Surface employees:				
Dumpers	2	2	-	4
Lamp men	1	1	1	3
Truck driver	1	-	-	1
Blacksmith	1	-	-	1
Blacksmith's helper	1	-	-	1
Washer operator	1	-	-	1
Washer mechanics	1	1	-	2
Car dropper	1	-	-	1
Car cleaners	2	-	-	2
Tipple foreman	1	-	-	1
Sampler	1	-	-	1
Total	13	4	1	18
Supervisory employees:				
Superintendent	1	-	-	1
Master mechanic	1	-	-	1
Clerks	2	-	-	2
Storeroom clerk	1	-	-	1
Total	5	-	-	5
Total employees	74	57	25	156

Summary

Percent of mine mechanized	100
Hours per shifts	8
Shifts per day	2
Estimated recovery of portion of coal bed mined, in panels, percent	84
Estimated recovery of total coal bed, in panels, percent	75
Average number mechanized unit-shifts per day in retreating panel	6
Man-shifts per day in retreating panel	66
Man-shifts per day, mechanized units, panels, development, and pillar mining	88
Total man-shifts per day, underground	133
Total man-shifts per day, surface and underground	156

	Raw coal[1]	Clean coal
Average daily production, mine, tons	2,017	1,821
Average daily production, retreating panel, tons	1,560	1,408
Average production per man-shift, retreating panel, tons	23.6	21.3
Average production per man-shift, mechanized units, tons	22.9	20.7
Average production per man per day, underground, tons	15.2	13.7
Average production per man employed per day, tons	12.9	11.7
Average production per pound of explosive, tons	5.0	4.5

[1] Estimated, includes all material sent to cleaning plant.

Mine 59

Mine 59, situated in southwestern Pennsylvania, is opened by three slopes and two shafts. One slope, which is 900 feet long with a 25 percent grade, is equipped with a 48-inch belt conveyor. This belt transports the raw coal to the tipple from a rotary dump at the slope bottom. Two ventilating fans, operated exhausting, furnish about 290,000 cubic feet of air per minute, circulated through 12 air splits in the mine.

The Pittsburgh coal bed, which averages 84 inches thick in this area, is mined. The coal is overlain by 10 to 13 inches of shale, commonly called draw slate, that is blasted and loaded with each cut of coal. This shale is overlain by a stratum of laminated coal, locally termed "wild coal," that ranges from 3 to 10 inches thick. This wild coal is left in place and is the roof. The laminated coal is overlain by a bed of dark shale that ranges from 6 to 10 feet thick. This shale is overlain by a 30-foot stratum of massive sandstone. The remaining overburden comprises a series of shales, limestones, sandstones, and thin coal beds. The average overburden in working sections of the mine is 400 feet in thickness. The bottom is hard shale that ranges from 2 to 6 inches thick. This shale is underlain by a 2- to 4-foot stratum of fire clay, which heaves under pressure when wet (see fig. 18).

Operations at this mine are completely mechanized and 5,400 tons of clean coal are produced daily in four 8-hour shifts. Only mechanized-unit crews work on a 4-shift basis, and these crews relieve each other at the working faces. Actual time spent at the working face, including lunch period, is 6 hours. All other employees work three 8-hour shifts a day. The average yield of clean coal is 65 percent of the raw material, including coal, draw slate, and other impurities. Therefore, the average weight of material hoisted per day is about 8,300 tons.

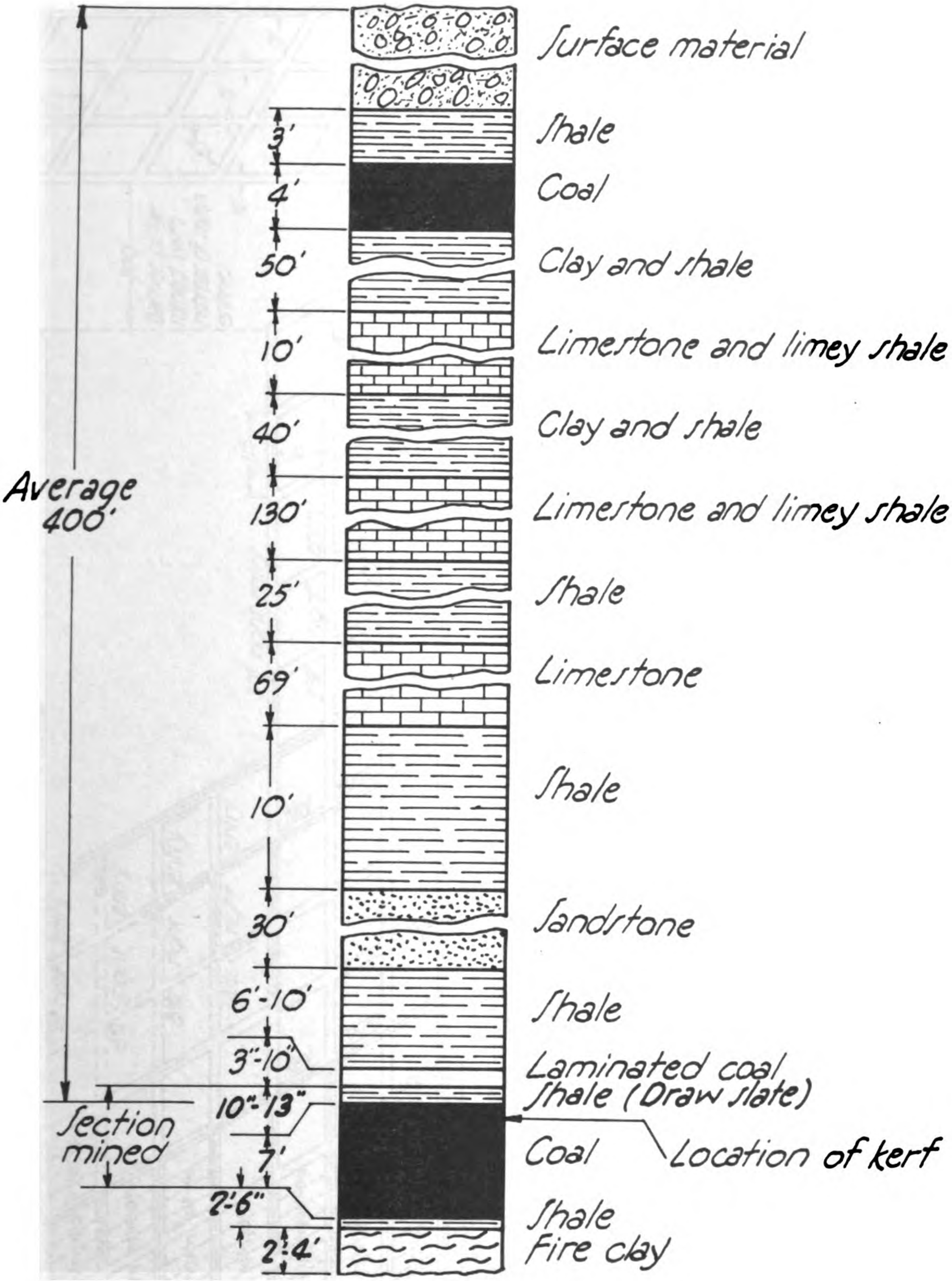


Figure 18. - Section of coal bed and overburden at mine 59.

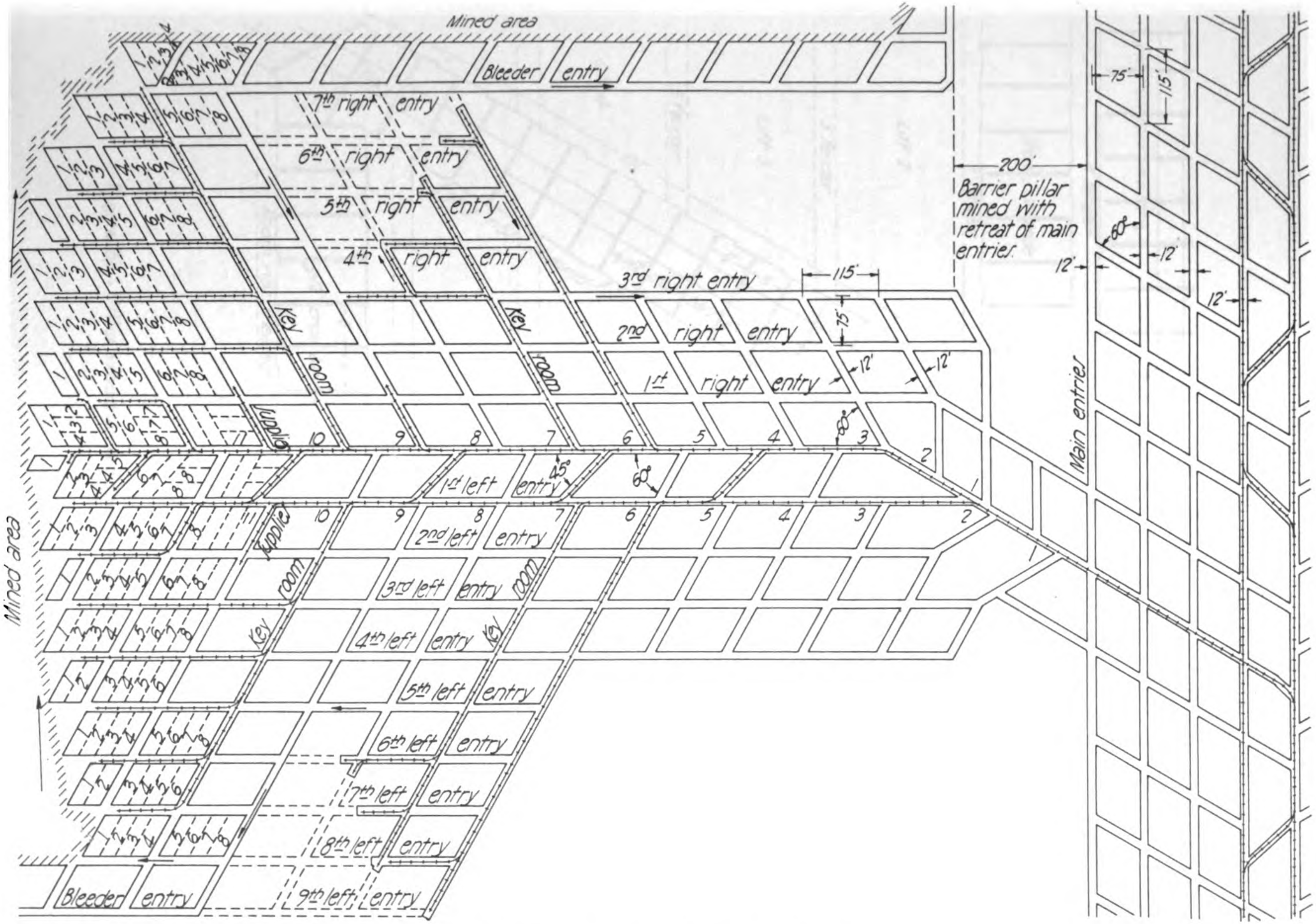


Figure 19. - Mining method at mine 59.

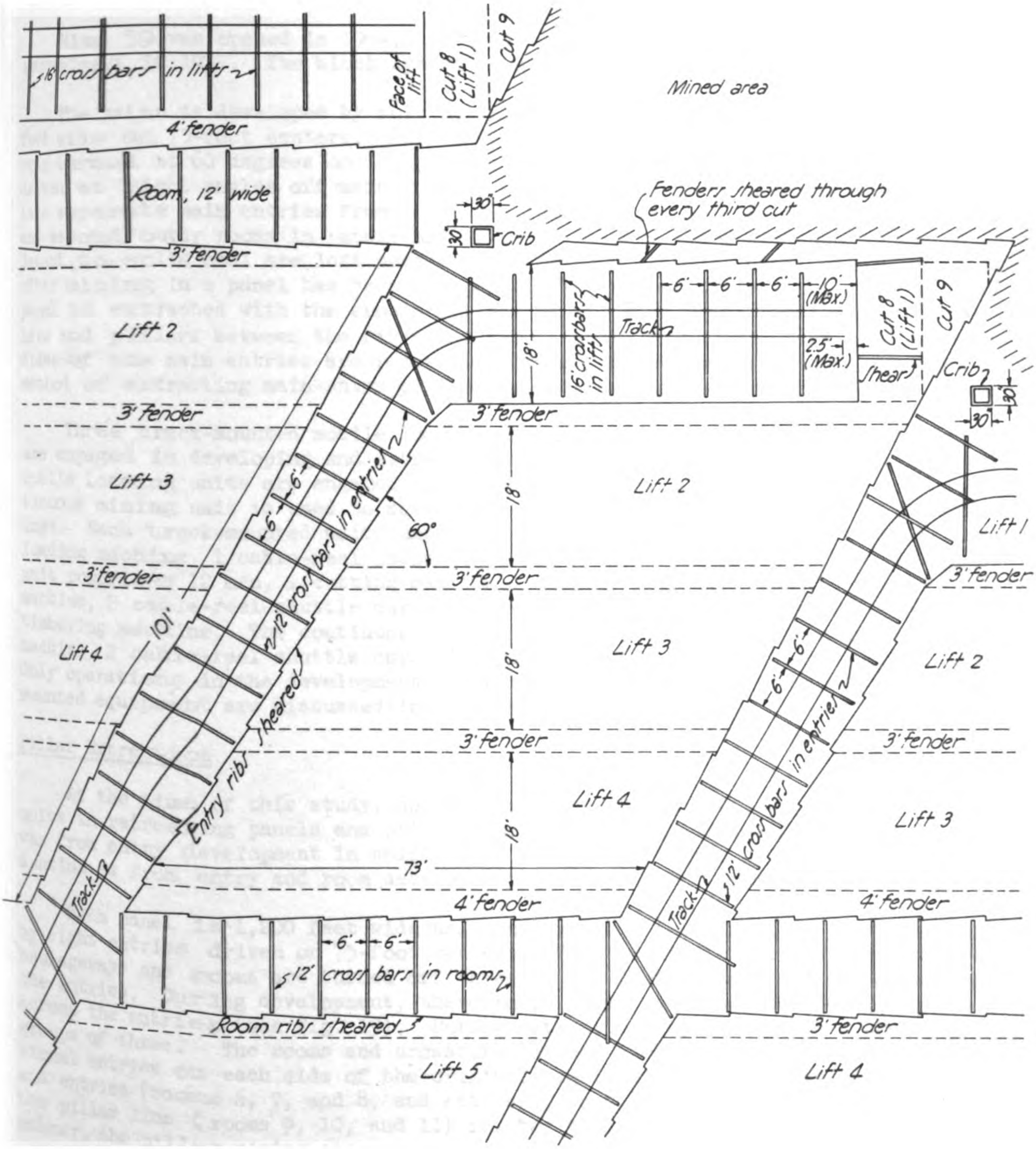


Figure 20. - Pillar extraction and timbering at mine 59.

Mining Method

Mine 59 was opened in 1909, and hand-loading was practiced until operations were mechanized in 1937. The block system of mining is followed and pillars are extracted.

The mine is developed by multiple main and panel entries, which are driven 12 feet wide on 75-foot centers. Main entries are driven in sets of eight with crosscuts turned at 60 degrees on 115-foot centers. Panel entries, in sets of eight, are driven at right angles off main entries (see fig. 19). Two hundred-foot barrier pillars separate main entries from the first rooms in panels. Pillars between the first and second outby rooms in panels and a row of pillars along one side of the panel adjacent to solid coal are left unmined to provide a bleeder entry for the caved area after mining in a panel has been completed. The row of pillars along the side of the panel is extracted with the subsequent mining of an adjacent panel. The barrier pillars and pillars between the first and second outby rooms of panels left on both sides of the main entries are recovered during retreat mining in main entries. The method of extracting main-entry pillars is the same as the method followed in panels.

Three track-mounted mobile loading units and one trackless mobile loading unit are engaged in developing and extracting room pillars in panels. Four track-mounted mobile loading units are engaged in the second mining in an adjacent mine. One continuous mining unit is used to develop haulageways for pillar mining in the old workings. Each track-mounted unit comprises 15 men, 1 cutting machine, 1 drill, 1 mobile loading machine, 1 cable-reel locomotive, and 1 timbering machine. The trackless unit comprises 12 men, 1 cutting machine, 1 drill, 1 crawler-mounted mobile loading machine, 2 cable-reel shuttle cars, 1 elevating conveyor, 1 car-spotter hoist, and 1 timbering machine. The continuous mining unit comprises 4 men, 1 continuous mining machine, 2 cable-reel shuttle cars, 1 elevating conveyor, and 1 car-spotter hoist. Only operations in the development and extraction of pillars in panels with track-mounted equipment are discussed in this report.

Pillar Extraction

At the time of this study, about 90 percent of the total production was from units in retreating panels and pillar mining in the adjacent mine. About 10 percent was from entry development in solid coal. In panels, about 35 percent of the production is from entry and room development and 65 percent from pillar mining.

Each panel is 1,200 feet wide and usually 1,800 feet long. A panel is developed by eight entries driven on 75-foot centers. • The two middle entries are the main haulageways and rooms are turned off these on 115-foot centers and at 60 degrees to the entries. During development, these rooms serve as crosscuts and are driven only across the entries (see fig. 19). During retreat mining, these rooms are extended in groups of three. The rooms and crosscuts between them provide three to five additional entries on each side of the original panel entries. The development of rooms and entries (rooms 6, 7, and 8, and entries 5 to 9, fig. 19) is completed at the time the pillar line (rooms 9, 10, and 11) reaches this newly developed area. In this manner, the pillar mining sequence is not interrupted.

Pillars are 60-degree parallelogram-shaped blocks with side measurements of 101 feet by 73 feet. Each pillar comprises four lifts. Each lift is driven 18 feet wide and is completed in an average of nine cuts. A 3-foot fender of solid coal, sheared through every third cut, is left on the gob side of the lift to help support the roof and to prevent caved rock from sloughing into the roadway (see fig. 20). After a lift has been completed and the track recovered, the fender is blasted, if necessary, and a fall occurs.

As shown in figure 19, all pillars along the cave line are divided into lifts, which are numbered. All lifts bearing the same number are started at the same time and, if worked on schedule, are completed at about the same time. In this way, working places in pillars and rooms under development provide 18 or 20 working faces at all times. During retreat mining in a panel, the cave line is almost straight and perpendicular to the entries. However, two or three rows of pillars next to the gob of an adjacent mined-out panel are mined slightly in advance to form a small curve in the cave line in order to lessen pressure on these pillars from the old gob. As pillar extraction in a panel nears completion, the opposite end of the pillar line also is moved ahead so that the cave line assumes the shape of an arc as the last pillars are mined.

Pronounced face and butt cleats are present in the coal, but double-shearing of coal faces provides advantages that equal any that might be derived from mining parallel and perpendicular to the cleats.

A track-mounted mobile loading unit crew in a pillar section follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Driller	1
Shot firer	1
Motorman	1
Brakeman	1
Tracklayers and switchlayers	4
Timbermen	2
Foreman	1
Total	15

The cycle of operation follows:

1. Timber.
2. Lay track.
3. Drill.
4. Cut.
5. Charge and blast.
6. Load coal.

1. Timber. - All lifts, rooms, and entries are timbered with wood crossbars set not over 6 feet apart and to within 10 feet of the face. Lifts are timbered with 16-foot bars and rooms and entries with 12-foot bars. Lagging is used over the bars, where needed. A section timbering crew comprises two men who are assigned a track-mounted timbering machine equipped with hydraulic lifting arm and circular saw. The machine pulls a supply truck loaded with crossbars, legs, lagging, and cap pieces. In pillar mining, cribs are constructed in the entries inby each working lift and opposite the fender to prevent caves from advancing onto roadways (see fig. 20). Cribs are recovered for future use, where possible. Three-piece timber sets are not recovered. An average of 19.5 tons of raw coal and draw slate is mined per crossbar used.

2. Lay track. - Two tracklayers and two switchlayers are a part of each section crew. Track is laid to within 30 inches of the working face and is recovered after each lift has been completed.

3. Drill. - Three holes, one in the center and one at each rib, are drilled in the draw slate. These holes are started in coal at the base of the slate and are inclined upward and stopped when they reach the wild coal. Two holes are drilled near the bottom of the coal bed, 3-1/2 feet from each rib in 12-foot places; in 18-foot places, three holes are drilled, two near each rib and one near the center. One man drills with a track-mounted electric auger-type drill.

4. Cut. - Horizontal kerfs are made in all coal faces about 8 to 12 inches below the draw slate. Vertical shear cuts are made along both ribs of rooms and entries from the kerf to the bottom of the coal. In pillar mining, the inby rib adjacent to the protective fender is sheared and another shear cut is made about 6 feet from the opposite rib. Protective fenders are sheared through every third cut. Coal is cut with a track-mounted universal-type cutting machine operated by two men.

5. Charge and blast. - Holes in the draw slate are charged with three cartridges of permissible explosive and coal holes with five or six cartridges. The explosive is detonated electrically, one hole at a time. The slate is blasted first and the coal last. Approximately 4 tons of raw coal and draw slate are produced per pound of explosive used.

6. Load coal. - Coal and slate are loaded together into 10-ton mine cars with track-mounted mobile loading machines. Two men comprise the loading crew. Mine car changes are made by two men with a cable-reel locomotive.

Loaded coal trips are gathered and transported to the belt slope with trolley locomotives.

Roof Action

In pillar mining, roof is supported by systematic timbering, by the protective fender inby each lift, and by cribs placed where needed to prevent caves from encroaching upon haulageways and working places. After the last cut has been removed from a lift, six or eight holes are drilled in the fender. The track and cribs are recovered, if possible. A fall crew recovers cribs under protection of safety props. The fender is then blasted, and the immediate roof and much of the sandstone cave and override the timbers. Caving usually follows the pillar mining very closely. As the pillar line advances, the entire overburden subsides. When mine floors are wet, bottom heaving occurs in areas where roof pressures become intensive. Maintaining pillar lines parallel to roof cleats does not offer enough advantages to justify altering the plan of development.

Recovery

An average panel, which includes the main-entry barrier pillar, has approximately 600,000 tons of coal in place. Each panel yields about 528,000 tons of coal, an average panel recovery of 88 percent.

Main entry chain pillars, barrier pillars, and pillars left in panels to maintain bleeder entries are extracted during retreat from a mined-out area. Based upon a comparison of tons of coal recovered with tons originally in place in large areas where mining has been completed, over-all mine recovery is estimated at slightly more than 80 percent.

Classification of Employees

	Shift				
Classification	1st	2d	3d	4th	Total
Mechanized units:					
Loading-machine operators	9	9	9	9	36
Loading-machine helpers	8	8	8	8	32
Cutting-machine operators	8	8	8	8	32
Cutting-machine helpers	8	8	8	8	32
Drillers	8	8	8	8	32
Shot firers	8	8	8	8	32
Timbermen	16	16	16	16	64
Motormen	9	9	9	9	36
Brakemen	7	7	7	7	28
Tracklayers and switchlayers	28	28	28	28	112
Shuttle-car operators	3	3	3	3	12
Foremen	8	8	8	8	32
Total	120	120	120	120	480
Other underground employees:					
Motormen	8	5	5	5	23
Brakemen	8	5	5	5	23
Ventilation men	8	6	6	6	26
Timbermen	3	3	3	3	12
Trackmen	4	4	4	4	16
Fall crew	2	2	2	2	8
Drainage men	10	8	7	6	31
Bonder	-	1	-	-	1
Wiremen	7	-	-	-	7
Dispatchers	1	1	1	-	3
Maintenance men	29	16	16	12	73
Maintenance foremen	3	2	1	-	6
Laborers (general)	4	3	3	3	13
Assistant foremen	2	2	2	-	6
Total	89	58	55	46	248
Total underground employees	209	178	175	166	728
Surface employees:					
Cleaning plant men	8	8	8	-	24
Cleaning plant foremen	1	1	1	-	3
Rotary dump operators	1	1	1	-	3
River men	2	2	2	-	6
Yard men (supplies)	10	-	-	-	10
Yard foreman	1	-	-	-	1
Maintenance men	15	3	2	-	20
Car shopmen	6	-	-	-	6
Lamp men	1	1	1	-	3
Laborers	6	-	-	-	6
Filter plant operator	1	-	-	-	1
Truck drivers (refuse)	2	2	2	-	6
Foremen	2	-	-	-	2
Total	56	18	17	-	91

Classification	Shift				Total
	1st	2d	3d	4th	
Supervisory employees:					
Superintendent	1	-	-	-	1
Mine foremen	1	-	1	-	2
Safety supervisor	1	-	-	-	1
Engineers	3	-	-	-	3
Clerks	11	-	-	-	11
Chemist and helper	2	-	-	-	2
Total	19	-	1	-	20
Total employees	284	196	193	166	839

Summary

Percent of mine mechanized	100
Hours per shift	8
Shifts per day, underground	4
Shifts per day, surface	3
Estimated recovery in panels, percent	88
Estimated over-all mine recovery, percent	80
Average yield, clean coal from raw coal, percent	65
Average number mechanized unit-shifts per day in panels	16
Man-shifts per day in panels	240
Man-shifts per day, mechanized units, panels, development and second mining	480
Total man-shifts per day, underground	728
Total man-shifts per day, surface and underground	839

	Raw coal[1]	Clean coal
Average daily production, mine, tons	8,300	5,400
Average daily production, panels, tons	4,800	3,120
Average production per unit-shift, panels, tons	300	195
Average production per man-shift, panels, tons	20.0	13.0
Average production per man-shift, mechanized units, tons	17.3	11.2
Average production per man per day, underground, tons	11.4	7.4
Average production per man employed per day, tons	9.9	6.4
Average production per pound of explosive, tons	4.0	2.6
Average production per cross bar used, tons	19.5	12.7

[1] Raw coal includes all material sent to cleaning plant.

Mine 60

Mine 60, situated in eastern Kentucky, is opened by a number of drifts driven from the outcrop into the coal bed. Eleven ventilating fans, seven operated exhausting and four blowing, furnish 466,000 cubic feet of air per minute, which is circulated through 14 air splits in the mine.

The Elkhorn No. 3 bed, which averages 45 inches thick and ranges from 30 to 60 inches thick in the area, is mined. In some areas, the coal is overlain by a stratum of rashy shale that ranges from a few inches to over 20 feet in thickness. The shale is overlain by a heavy stratum of sandstone, which sometimes immediately overlies the coal where the shale is absent. The remaining overburden is comprised of shales, thick sandstones, and thin coal beds. The thickness of the overburden ranges from a few feet at the outcrop to nearly 1,000 feet under the mountain tops. The coal is underlain by 10 inches of fire clay, which, in turn, is underlain by shale (see fig. 21).

Operations are about 78 percent mechanized and 6,100 tons of raw coal are produced daily in three 8-hour shifts.

Mining Method

The mine was opened in 1915. The room-and-pillar system of mining is followed and pillars are extracted. The mine is developed by multiple main and panel entries, which are driven on 50-foot centers. Haulage entries are 12 feet wide and air-course entries, 16 feet wide. Main entries are driven in sets of six and panel entries in sets of three. The direction and length of main entries are determined by property boundaries and outcrops. Panel entries usually are turned at right angles off main entries and are driven about 1,600 feet (see fig. 22). Barrier pillars, 225 feet wide, separate the main entries from the outby rooms in panels. Cleats in the coal and roof are not pronounced and do not affect the plan of development. The regional dip of the coal bed is about 1 percent northwest. Short dips and rolls that often require grading of main haulage entries occur frequently. Narrow, long, want areas, in which the coal has been entirely or partly replaced by rock, are encountered often.

At the time of this study, 7 track-mounted mobile loading units, 1 trackless mobile loading unit, and 204 contract hand loaders were engaged in developing rooms and extracting pillars. Five track-mounted mobile loading units, 1 trackless mobile loading unit, and 15 contract hand loaders were engaged in entry development. Ninety-four men, using hand-loaded shaking conveyors were driving panel entries and rooms. Conveyor units were not extracting pillars.

Each track-mounted unit comprises 13 men, 1 crawler-mounted mobile loading machine, 1 cutting machine, 1 coal drill, and 1 cable-reel locomotive. Each trackless unit comprises 11 men, 1 crawler-mounted mobile loading machine, 1 cutting machine, 1 coal drill, 1 shuttle car, 1 car hoist, and 1 cable-reel locomotive. Only operations in the development of rooms and extraction of pillars in panels with track-mounted equipment are discussed in this report.

Pillar Extraction

About 41 percent of the production is from pillar mining; 38 percent from room development; and 21 percent from entry development. About 46 percent of the coal produced from panels is from entries, rooms, and crosscuts and 54 percent from pillars.

Each panel is 400 feet wide and about 1,600 feet long. Room entries and rooms are equipped with track constructed with 30-pound rails. After panel entries have been developed, rooms are driven at right angles, usually off the outby entry. Rooms are driven 20 feet wide on 75-foot centers to a depth of 284 feet. Two rooms are usually under development; one about one-half room length ahead of the other (rooms 8 and 9, fig. 23). At the same time, pillars are being extracted from between the four preceding rooms (pillars A to F, fig. 23). These pillars are mined in a sequence to form cave lines 45 degrees to the entries. After pillars A to F have been extracted, development of room 8 has been completed and room 10 begun. Then mining of pillars A' to F' begins.

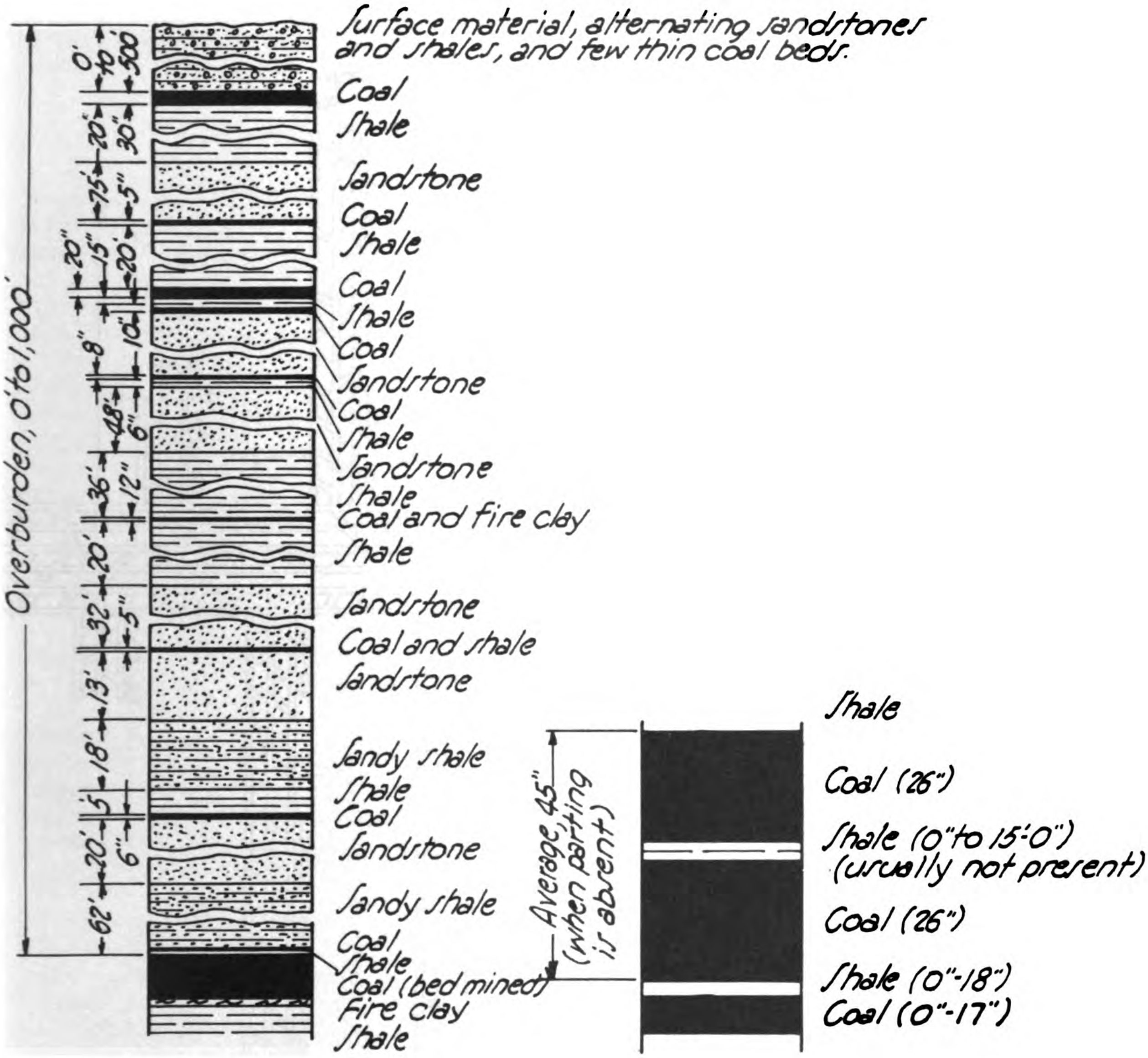


Figure 21. - Section of overburden and coal bed at mine 60.

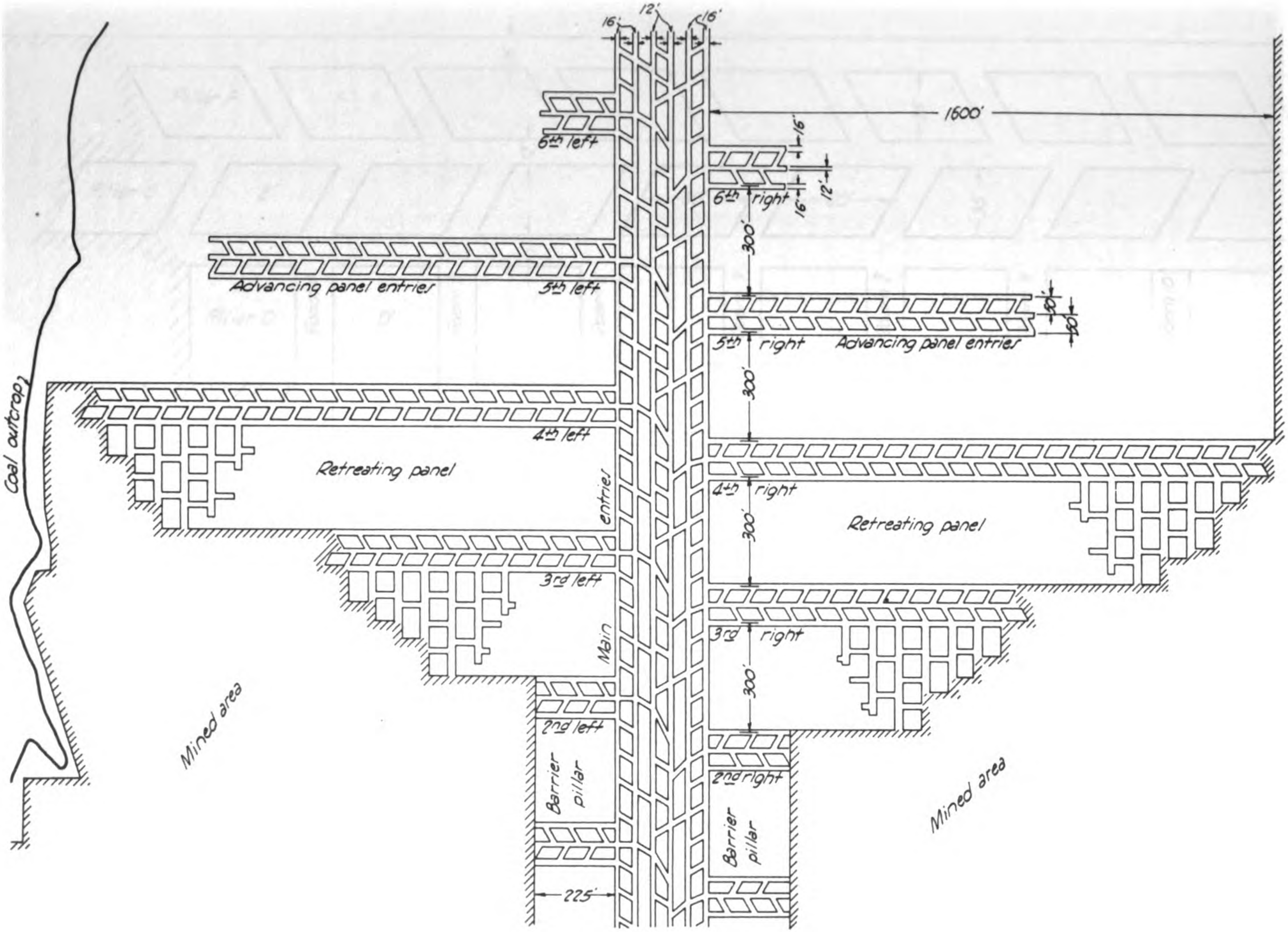


Figure 22. - Mining method at mine 60.

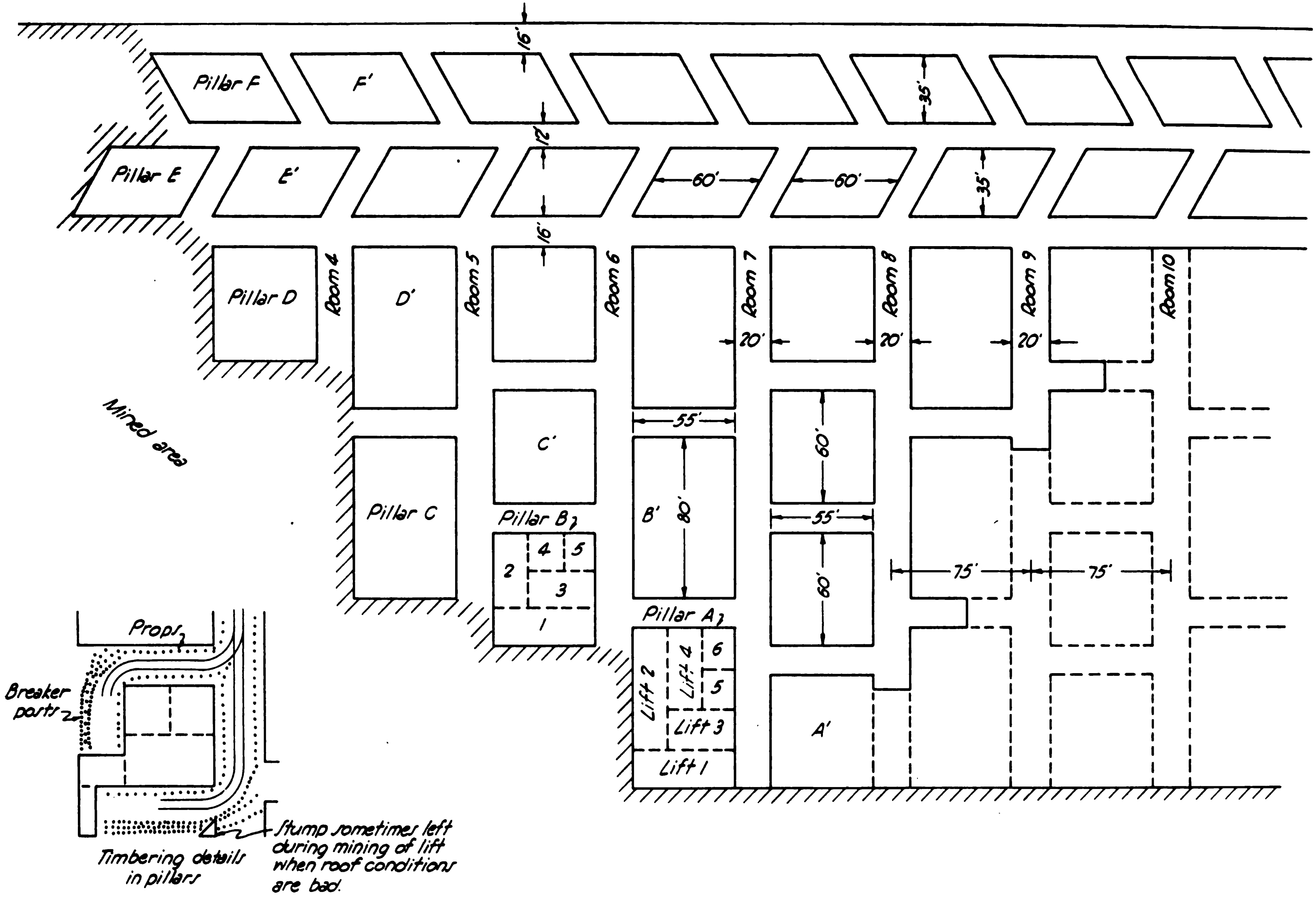


Figure 23. - Pillar extraction at mine 60.

Room pillars are rectangular blocks approximately 55 feet wide and either 60 or 85 feet long. Rows of room pillars alternate in number and length. One row has three pillars 85 feet long, and the next row has four pillars 60 feet long. In this system, crosscuts are staggered and wide areas of exposed roof in aligned crosscuts are avoided. Entry chain pillars are parallelogram blocks 36 feet wide and 60 feet long. The method followed in the extraction of individual pillars is the open-end system, with lifts taken off the two sides adjacent to the gob (see sequence of lifts, fig. 23). If roof conditions are unfavorable, a small stump of coal is left between the gob and the first cut in the lift. In these cases, the stump is partly recovered after the lift has been completed.

A mechanized unit crew in a track-loading section follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Shot firer	1
Clean-up man	1
Trackman	1
Timbermen	2
Haulage men	3
Foreman	1
Total	13

The cycle of operation follows:

1. Timber.
2. Lay track.
3. Cut and drill.
4. Charge and blast.
5. Load coal.

1. Timber. - During advance mining, one or two rows of props are set on each side of the track. Wood cross bars also are used, where necessary. Screw jacks are used as safety posts at the working faces and are replaced with permanent wood timbers as the faces are advanced. Four-inch aluminum H-beams are used with the screw jacks where roof conditions require. In pillar mining, one to three rows of breaker posts are set along the inby side of lifts along the gob to support the roof and to aid in breaking the roof as pillars are mined. Spacing of these breaker posts depends upon roof conditions, and, if necessary, they are grouped to form clusters along the gob. An average of 1.5 tons of coal is produced per prop and 37.8 tons per crossbar. Some wood crossbars are recovered during pillar mining and used again. Props are not recovered.

2. Lay track. - Thirty-pound steel rails are used in panel tracks. Track is advanced to within about 30 feet of the face, and the ends of the rails are equipped with end-of-track rerailers. Mine cars are pushed off the end of the track onto the mine floor to provide extra height for loading.

3. Cut and drill. - The coal is bottom cut with shortwall cutting machines. Machines are transported on track-mounted trucks. The two-man cutting crew also drills three or four holes per place, depending on the width of the coal face. Holes are drilled 6 feet deep near the top of the bed.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

4. Charge and blast. - Holes are charged with permissible explosive, which is detonated electrically, all at one time. Production per pound of explosive is estimated at 6.25 tons.

5. Load coal. - Coal is loaded into 2.7-ton mine cars with crawler-mounted mobile loading machines. The production per mechanized unit is about 125 tons per shift.

A cable-reel locomotive moves the loaded cars to a parting on the panel entry and returns empty cars to the loading machine. A trolley locomotive supplies the section with empty cars and transports the loaded cars to the main line where main line locomotives transport the loaded cars in trips to the surface.

Roof Action

The stratum of shale over the coal bed usually is not strong enough to support itself, and it is necessary to use both props and crossbars. Because of the bedding planes in the immediate overburden, the roof breaks and falls in large slabs in gob areas where pillars are being mined. In pillar mining, breaker posts form the cave line, and these posts bend and break as the span of mined area widens. Caving usually follows pillar mining closely. If recovery is high and no stumps of solid coal are left unmined, squeezing and bottom heaving do not occur. Apparently there is no difference in roof action under small or great thicknesses of overburden at this mine.

Recovery

The coal bed mined occurs in two benches separated by a thin parting near the bottom of the bed. The upper bench of coal, which is the portion of the bed usually mined, ranges from 34 to 50 inches in thickness and averages 45 inches thick in most sections of the mine. In some small areas, a parting occurs in the middle of the upper bench (see fig. 21). When this parting is over 24 inches thick, the undercut is made in the lower bench of coal, and the coal above this nonpersistent parting is not mined. In these areas, hand-loaded conveyors are used and pillars are not extracted. The company estimates the over-all recovery for the calendar year preceding this study at 87 percent of the portion of the bed mined in areas where pillars are extracted. Data relative to percent of recovery in panels were not available. Barrier pillars along main entries and main entry chain pillars are recovered on retreat from a mined area.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units (mobile loaders):				
Loading-machine operators	14	14	5	33
Loading-machine helpers	14	14	5	33
Cutting-machine operators	14	14	5	33
Cutting-machine helpers	14	14	5	33
Shot firers	14	14	5	33
Clean-up men	14	14	5	33
Trackmen	12	12	4	28
Timbermen	28	28	10	66
Motormen	14	28	7	49
Brakemen	28	14	8	50
Shuttle-car operators	3	3	1	7
Foremen	14	14	5	33
Total	183	183	65	431
Mechanized units (conveyors):				
Conveyor men (cutters, helpers, drillers, and loaders)	38	38	-	76
Motormen	2	1	-	3
Brakemen	1	2	-	3
Boom men	3	3	-	6
Foremen	3	3	-	6
Total	47	47	-	94
Contract hand-loading crews	109	110	-	219
Other underground employees:				
Dispatchers	1	1	1	3
Motormen	11	12	8	31
Brakemen	8	12	8	28
Trackmen and helpers	20	5	8	33
Wiremen and helpers	9	1	1	11
Timbermen and helpers	9	2	-	11
Brattice men	6	2	-	8
Track cleaners	1	-	7	8
Slatemen	19	6	13	38
Rock dusters	-	-	2	2
Pumpers	1	2	4	7
Ramp operator	1	-	-	1
Dust-control man	-	-	1	1
Rock drillers and helpers	-	-	4	4
Electricians and helpers	17	9	5	31
Bonders and helpers	-	2	2	4
Foremen	1	-	3	4
Total	104	54	67	225
Total underground employees	443	394	132	969

Classification	Shift 1st	Shift 2d	Shift 3d	Total
Surface employees:				
Tipplemen (including railroad-car handlers)	22	22	-	44
Tipple foremen	2	1	-	3
Cleaning-plant operators	1	1	-	2
Sand driers	1	1	-	2
Oilers	2	-	-	2
Bulldozer operators	2	2	-	4
Aerial-tram operators and helpers	2	2	-	4
Truck drivers	2	-	-	2
Timber checker	1	-	-	1
Lamp men	1	1	1	3
Shopmen	28	10	-	38
Laborers	2	-	-	2
Total	66	40	1	107
Supervisory employees:				
Mine superintendent	1	-	-	1
Mine foremen	3	1	-	4
Maintenance superintendent	1	-	-	1
Underground maintenance foreman	1	-	-	1
Shop foreman	1	-	-	1
Mining engineers	7	-	-	7
Mechanization engineer	1	-	-	1
Electrical engineer	1	-	-	1
Safety director and assistants	3	-	-	3
Office clerks and secretarial workers	6	-	-	6
Supply clerks	3	-	-	3
Total	28	1	-	29
Total employees	537	435	133	1,105

Summary

Percent of mine mechanized	78
Hours per shift	8
Shifts per day	3
Average daily production, panels, mobile loading units, tons	2,375
Average daily production, panels and entry development, mobile loading units, tons	4,125
Average daily production, conveyor units, tons	660
Average daily production, contract hand-loaders, tons	1,315
Average daily production, mine, tons	6,100
Mobile loader unit shifts per day	33
Average production per mobile loading unit per shift, tons	125
Average number man-shifts per day on mobile loading units	431
Average production per man-shift, mobile units, tons	9.6
Average number man-shifts per day on conveyor units	94
Average production per man-shift, conveyor units, tons	7.0
Average number man-shifts per day underground, chargeable to mobile loaders	583
Average production per man underground per day, chargeable to mobile loaders, tons	7.1
Average number man-shifts per day underground, chargeable to conveyor units	118

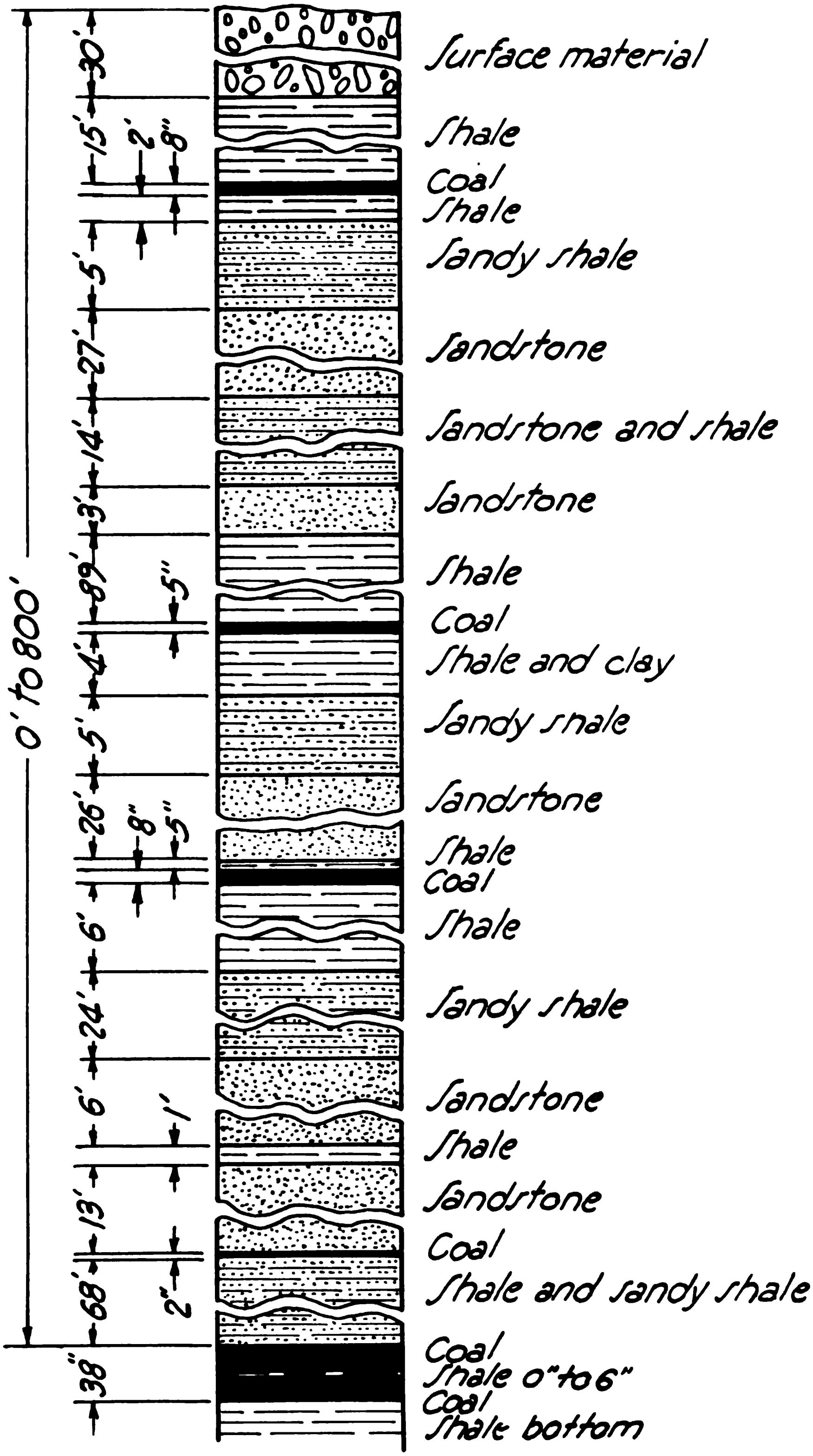


Figure 24. - Section of overburden and coal bed at mine 61.

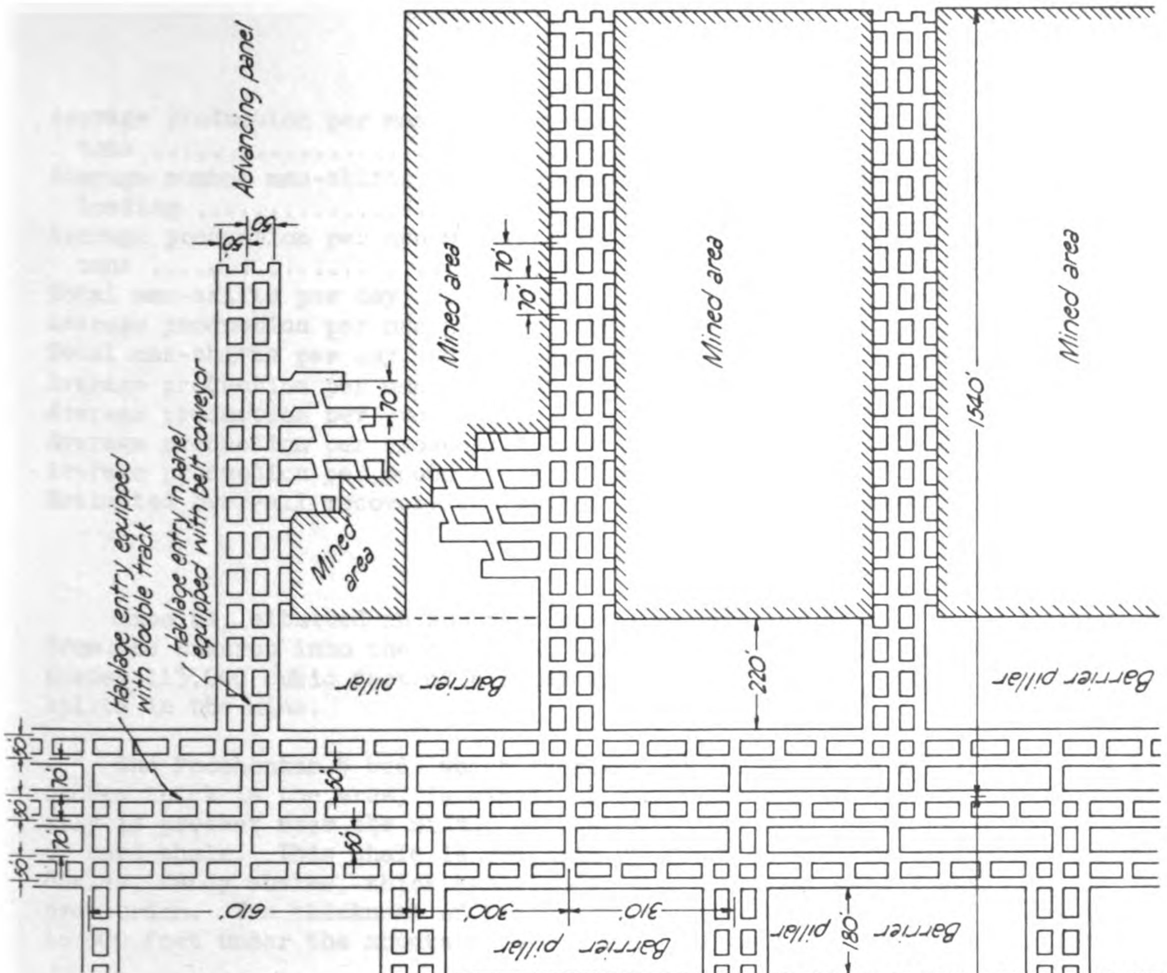


Figure 25. - Mining method at mine 61.

Average production per man underground per day, chargeable to conveyor units, tons	5.6
Average number man-shifts per day underground, chargeable to contract hand loading	268
Average production per man underground per day, chargeable to hand loaders, tons	4.9
Total man-shifts per day, underground	969
Average production per man per day, underground, tons	6.3
Total man-shifts per day, surface and underground	1,105
Average production per man employed per day, tons	5.5
Average production per prop, tons	1.5
Average production per crossbar, tons	37.8
Average production per pound of explosive, tons	6.25
Estimated over-all recovery in portion of bed mined, percent	87.0

Mine 61

Mine 61, situated in southern West Virginia, is opened by four drifts driven from the outcrop into the coal bed. One ventilating fan, operated exhausting, furnishes 115,000 cubic feet of air per minute, which is circulated through five air splits in the mine.

The Pocahontas 4 bed, which averages 38 inches thick and ranges from 36 to 40 inches thick in the area, is mined. A shale parting as much as 6 inches thick usually is present near the middle of the bed. The coal is overlain by a thin stratum of hard shale. This shale is overlain by about 90 feet of shales and sandy shales. Shales, sandy shales, thick sandstones, and thin coal beds constitute the remaining overburden. The thickness of the overburden ranges from a few feet at the outcrop to 800 feet under the mountain tops. The coal is underlain by shale (see fig. 24).

Operations are 100 percent mechanized and 2,100 tons of clean coal are produced daily in two 8-hour shifts. The yield of clean coal is about 92 percent. Therefore, the average daily production of raw coal is estimated at 2,283 tons.

Mining Method

The mine was opened in 1941. The room-and-pillar system of mining is followed and pillars are extracted. The mine is developed by multiple main and panel entries. Main entries are driven in sets of six and are developed in pairs on 50-foot centers separated by 50-foot barrier pillars (see fig. 25). The entries of the two outer pairs are 20 feet wide and are return airways. The middle two entries are intake airways. One of the middle entries is the main haulageway and is driven 22 feet wide and equipped with double track. Panel entries are turned at right angles off both sides of main entries. Panel entries, 20 feet wide on 50-foot centers, are driven in sets of three about 1,540 feet from the main haulage entry. Rooms are turned at right angles on both sides off panel entries and are driven 35 feet wide on 70-foot centers, to a depth of 300 feet. Barrier pillars, which separate the main entries from the outby rooms in panels, are 220 feet wide on the side nearest the main haulageway and 180 feet wide on the opposite side. Cleats in the coal and roof are not pronounced and do not affect the plan of development. The coal bed is generally flat lying, but slight dips occur locally. At the time of this study, 25 mechanized units were in operation:

15 units hand-loading onto conveyors and two mobile-loading units loading onto conveyors in the development of entries and rooms and pillar extraction in panels.

4 units hand-loading onto conveyors in main entry development.

4 units hand-loading onto conveyors in the extraction of main entry chain and barrier pillars.

Each unit hand-loading onto conveyors comprises four men, one cutting machine, one coal drill, one chain face conveyor, and one chain room conveyor. Each mobile loading unit consists of seven men, one crawler-mounted mobile loading machine, one cutting machine, one coal drill, two chain face conveyors, and two chain room conveyors. Four conveyor units normally comprise a section or panel crew, except that in one panel, the two loading-machine units perform the work and no conveyor units are used. In each panel, one clean-up man and one loading-head man are employed. One foreman is used in each panel. Panel entry transportation is with a 26-inch belt conveyor, and mine cars are spotted on the main entry with a car hoist.

Pillar Extraction

About 60 percent of the coal produced is from entries, rooms, and crosscuts and 40 percent from pillars.

Each panel is 610 feet wide and 1,180 feet long. Two panel entries are turned and driven a short distance as the main entries are advanced. When the belt is installed and production begins in a panel, a third entry is begun and driven with the original two entries. As the entries advance, rooms are driven at right angles off the outby entry and pillars are mined on advance of the panel. Rooms are developed and pillars are mined on the inby side on retreat from the panel. Usually, 17 rooms are driven from each side of a panel. Two rooms usually are under development, one about half a room length ahead of the other (rooms 6 and 7, fig. 26). At the same time, pillar extraction begins on the pillars between rooms 3, 4, 5, and 6. Pillars are mined in the order A to E. After pillar C has been mined, the conveyor unit begins developing room 8. Room 6 will have been developed and mining of pillar E begins. The outby 20 feet of each room pillar adjacent to the outby entry is not mined and is left to protect the airway.

After the panel entries have been developed and mining of rooms and room pillars on the outby side of the panel is completed, development of rooms on the inby side is begun. These rooms are developed and room pillars are extracted on retreat, beginning at the inby end of the panel. Panel-entry chain pillars and room stumps on the outby entry are not extracted. Main-entry chain and barrier pillars are mined during retreat from a section of the mine.

Room pillars are about 35 feet wide and 60 feet long. The open-end system of pillar extraction is followed. In sections where the coal is hand loaded onto conveyors, cuts are taken off the ends of the pillar. In the section where the coal is loaded with mobile loading machines, lifts 30 feet wide are driven from the side of the pillar. Each lift comprises about five cuts . (See sequence of cuts, fig. 26.) Two working places are assigned to each mobile loading machine, and each working place is equipped with a face conveyor and a room conveyor.

The cycle of operation follows:

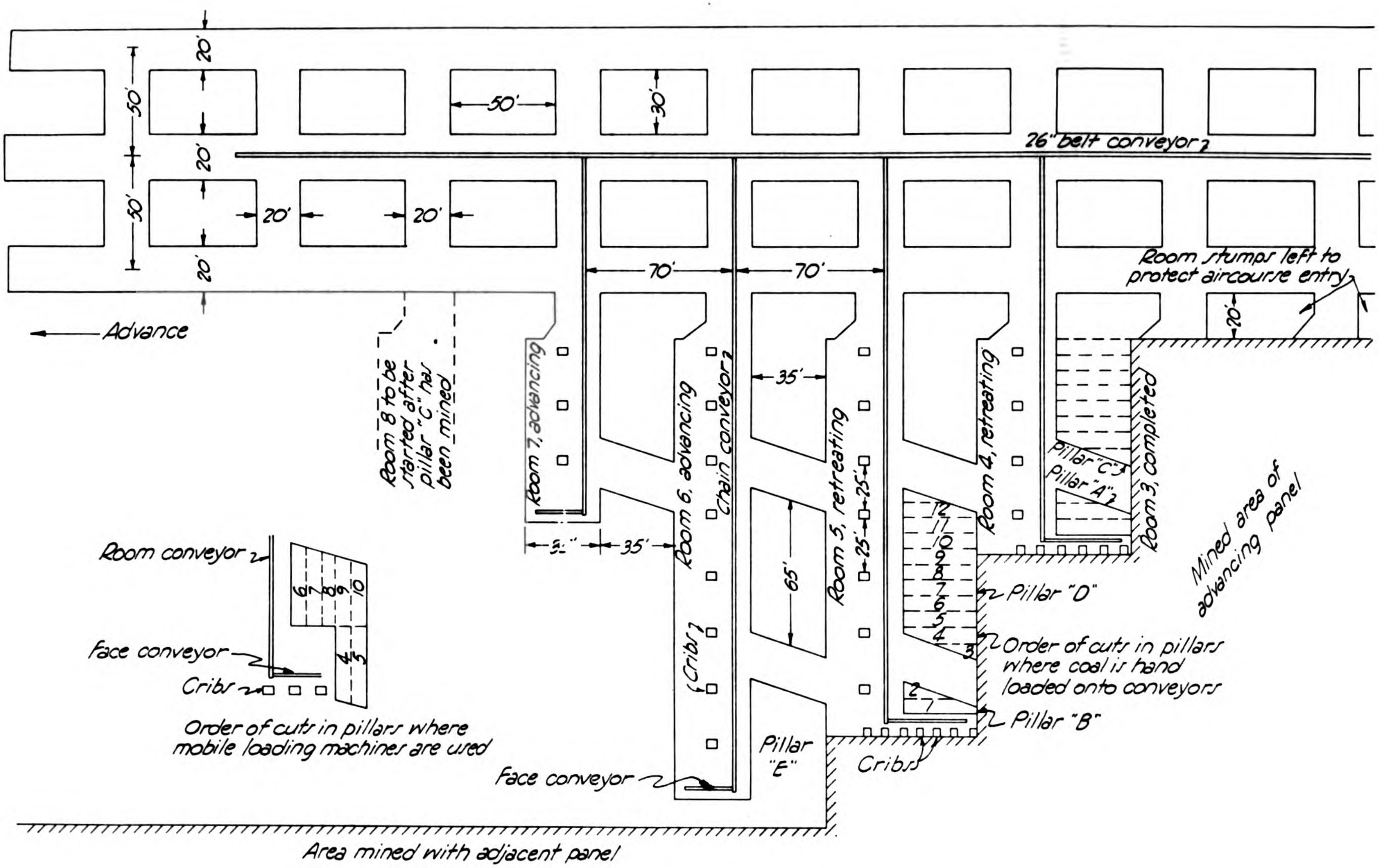


Figure 26. - Pillar extraction at mine 61.

1. Cut and timber.
2. Drill and extend conveyors.
3. Charge and blast.
4. Load coal.

1. Cut and timber. - The coal is bottom cut with shortwall cutting machines equipped with 7-foot cutter bars. Wood props on 5-foot centers and in rows 5 feet apart are set as working places are advanced. Cribs are installed about every 25 feet as the rooms are advanced (see fig. 26). In pillar mining, cribs 6 to 10 feet apart are installed along the face conveyor next to the gob. These cribs are used to assist in breaking the roof and are recovered and used again. Breaker posts are set 2 to 3 feet apart between cribs along the cave line. Safety posts are set about 6 feet apart between the face conveyor and the coal face. Props are seldom recovered and an average of 3.5 tons of coal is produced per prop used. Crossbars are used, where necessary. The roof over the haulage road in advancing main entries is bolted after the top has been brushed.

2. Drill and extend conveyors. - About five holes are drilled just above the shale parting with hand-held electric auger drills. No drilling and blasting is required in pillar mining with hand-loading conveyor units. The face conveyor is moved nearer the face, and the crew shortens or extends the room conveyors by removing or adding sections.

3. Charge and blast. - Holes are charged with four cartridges of permissible explosive, which is detonated electrically, one hole at a time. Production per pound of explosive is estimated at 8.0 tons.

4. Load coal. - Coal is loaded onto chain face conveyors, which discharge onto chain room conveyors. Room conveyors discharge the coal onto 26-inch belt conveyors in the panel entries. The panel belts transport the coal to loading stations on the main entries where it is loaded into mine cars. Mine cars, which have a capacity of 3-1/4 tons, are spotted at the belt head with car hoists. The coal is transported to the surface by trolley locomotives in trips of 30 loaded cars.

Roof Action

The stratum of shale overlying the coal bed usually is strong enough to support itself during advance mining. In pillar mining, the roof rock bends before breaking, and cribs are used to assist in breaking the roof. The roof has a laminated structure and falls in the gob areas in the form of large thick slabs. Caving does not always follow pillar mining closely. However, squeezes seldom occur. Apparently, there is no difference in roof action under small or great thicknesses of overburden at this mine.

Recovery

Panel entry chain pillars and the room pillars left adjacent to the outby panel entry are not recovered. Main entry chain pillars and barrier pillars are mined on retreat from a mined-out area. Probably over-all mine recovery is higher than the recovery in panels. However, data were not available to compute either panel or over-all mine recovery.

Classification of Employees

	Shift			
Classification	1st	2d	3d	Total
Mechanized units:				
Loading-machine operators	2	2	-	4
Loading-machine helpers	2	2	-	4
Cutting-machine operators	25	25	-	50
Cutting-machine helpers	25	25	-	50
Drillers and shot firers	4	4	-	8
Timbermen	2	2	-	4
Belt operators (boom men)	5	5	-	10
Conveyor men (hand loaders)	44	44	-	88
Foremen	4	4	-	8
Total	113	113	-	226
Other underground employees:				
Motormen	6	5	-	11
Brakemen	6	5	-	11
Wiremen	2	-	-	2
Pipemen	6	-	-	6
Trackmen	8	-	-	8
Timbermen	3	-	-	3
Brattice men	6	-	-	6
Electricians	5	1	-	6
Supply men	-	-	5	5
Rockmen	5	4	-	9
Greasers	1	1	-	2
Laborers	2	-	-	2
Beltmen	-	-	11	11
Fire bosses	-	-	2	2
Foremen	4	4	-	8
Total	54	20	18	92
Total underground employees	167	133	18	318
Surface employees:				
Superintendent	1	-	-	1
Mine foreman	1	-	-	1
Clerks	4	-	-	4
Engineers	2	-	-	2
Tipplemen	2	2	-	4
Slate pickers	10	-	-	10
Sand drier	1	-	-	1
Car repairmen	4	-	-	4
Truck drivers	6	2	-	8
Blacksmiths and helper	3	-	-	3
Outside foremen	3	-	-	3
Laborers	2	-	-	2
Chain repairman	1	-	-	1
Lamp men	1	1	-	2
Pipe fitter	1	-	-	1
Carpenters	2	-	-	2
Firemen	2	1	1	4
Machinists	4	2	-	6

Classification	Shift 1st	Shift 2d	Shift 3d	Total
Surface employees (Cont.):				
Electricians	4	1	-	5
Welder	1	-	-	1
Substation man	1	-	-	1
Car droppers	4	-	-	4
Greaser	1	-	-	1
Car trimmer	1	-	-	1
Total	62	9	1	72
Total employees	229	142	19	390

Summary

Percent of mine mechanized	100
Hours per shift	8
Average yield, clean coal from raw coal, percent	92
Mobile loading units, shifts per day	4
Conveyor units, shifts per day	46
Average number man-shifts per day, mobile loading units	34
Average number man-shifts per day, conveyor units	192
Average number man-shifts per day, all mechanized units	226
Total man-shifts per day, underground	318
Total man-shifts per day, surface and underground	390

	Raw coal[1/]	Clean coal
Average daily production, mine, tons	2,283	2,100
Average daily production, mobile loading units, tons	478	440
Average daily production per mobile loading unit, per shift, tons	120	110
Average daily production, conveyor units, tons	1,805	1,660
Average daily production per conveyor unit, per shift, tons	39	36
Average production per man-shift, mobile loading units, tons	14.1	12.9
Average production per man-shift, conveyor units, tons	9.4	8.6
Average production per man-shift, all mechanized units, tons	10.1	9.3
Average production per man per day, underground, tons	7.2	6.6
Average production per man employed per day, tons	5.9	5.4
Average production per pound of explosive, tons	8.7	8.0
Average production per prop, tons	3.8	3.5

1/ Raw coal includes all material sent to tipple.

Mine 62

Mine 62, situated in southern West Virginia, is a group of individual mines. Four of these mines were operating at the time of this study. The main-line haulage from the mines is on the surface. Each mine is equipped with one ventilating fan, operated exhausting, which circulates about 30,000 cubic feet of air per minute through one continuous circuit in the mine.

The Five-Block coal bed, which ranges from 6 to 12 feet thick in the area, is mined. The bed occurs near the mountain tops, and the outcrops on the slopes of the ridges limit operations to long, narrow areas of coal. Many want areas in which all or part of the coal has been replaced with soft clay and other unconsolidated material occur in the bed. These areas are presumed to be the result of past fires. The overburden over these areas generally is caved and shattered. Because of the irregular shape of areas to be mined, operations are limited to a number of small mines instead of one large mine. Three thin partings of bone occur in the coal bed, but these partings are not regular in thickness or extent.

The coal is overlain by 12 to 18 inches of rashy coal, which generally is supported with timbers. In some areas, the rash is taken down, loaded separately from the coal, and wasted on the surface. The rash generally is overlain by 2 to 24 inches of weak shale. Sandy shales, thick sandstones, and one thin coal bed constitute the remaining overburden. The overburden ranges from a few feet at the outcrop to 200 feet under the mountain tops. The coal is underlain by 1 to 5 inches of fire clay, and the fire clay is underlain by shale (see fig. 27).

Operations are 100 percent mechanized and about 2,700 tons of raw coal are produced daily in three 8-hour shifts.

Mining Method

Mining operations began in 1941. The room-and-pillar system of mining is followed and pillars are extracted. Individual mines are developed by entries driven in pairs on 60-foot centers. Rooms are turned at 60 degrees to the right, left, or from both sides of entries at intervals of 75 feet (see fig. 28). Room depths are limited by outcrops, want areas, or adjacent mined areas. All entries, rooms, and crosscuts are driven 20 to 22 feet wide. The size of the area to be mined determines the plan of mining. Cleats in the coal and roof are not pronounced and do not affect the plan of development. The regional dip of the coal bed is 2 percent northwest.

Six mechanized units were operating in four mines at the time of this study. Each unit normally consists of 13 men, 1 mobile loading machine, 1 cutting machine, 1 coal drill, and 1 cable-reel trolley locomotive. In the two mines where two mechanized units are operated, a trolley locomotive transports loaded coal trips to the main line and supplies the two units with empty mine cars.

Pillar Extraction

About 60 percent of the coal produced is from entries, rooms, and crosscuts; and 40 percent from pillars.

During entry advance, some rooms are turned and driven only a short distance to provide enough working places. When entries reach coal limits, development of rooms begins at the inby end. Two or three rooms on one side of entries are under development at a time (rooms 6 and 7, fig. 28). At the same time, pillars are being extracted from between three preceding rooms (pillars 1, 2, 3, 4, and 5, fig. 28). These pillars are extracted to form pillar lines 60 to 70 degrees to the entries. Pillar lines extend across the entries and into rooms on the opposite side of the entries.

Room pillars are 44 feet wide and about 65 feet long. Entry chain pillars are 40 feet wide and 55 feet long. The open-end system of pillar extraction is followed. Lifts, 20 to 22 feet wide, are mined from the inby ends of pillars. Each lift comprises about five cuts (see fig. 29). Small fenders are left adjacent to clay-filled want areas and on the inby side of lifts where caved rock from gob areas might spill onto the roadways. These fenders crush as the cave line advances.

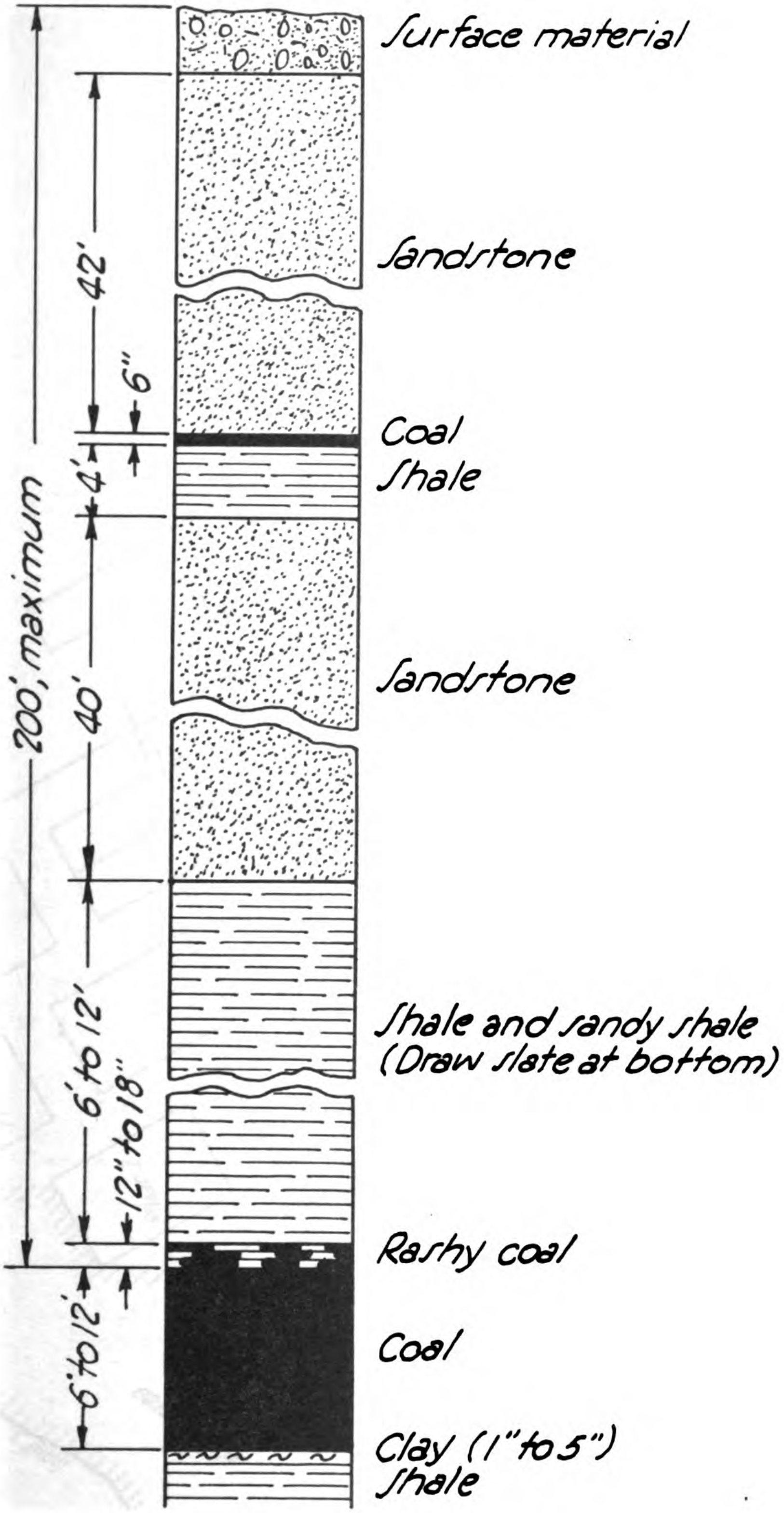


Figure 27. - Section of overburden and coal bed at mine 62.

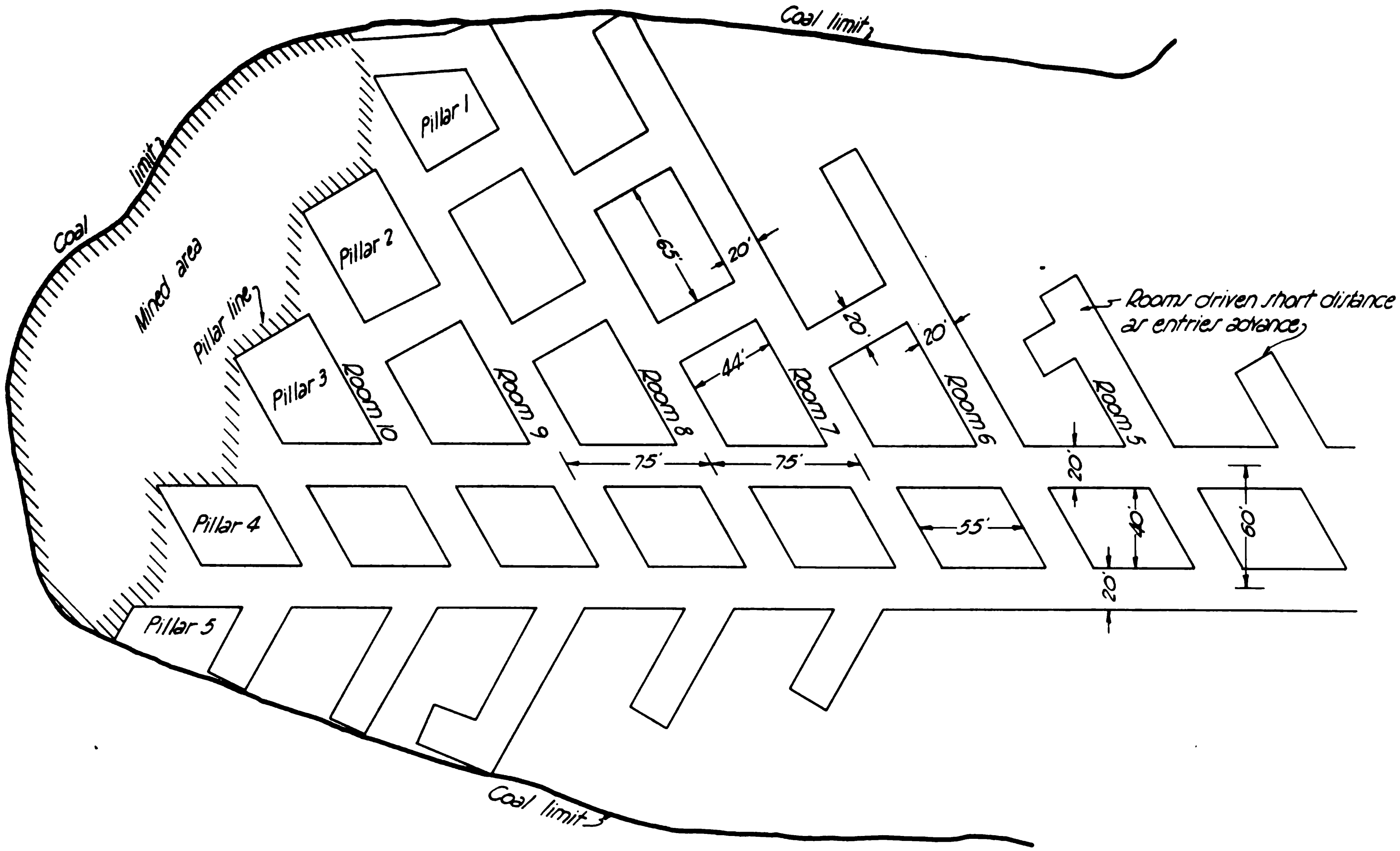


Figure 28. - Mining method at mine 62.

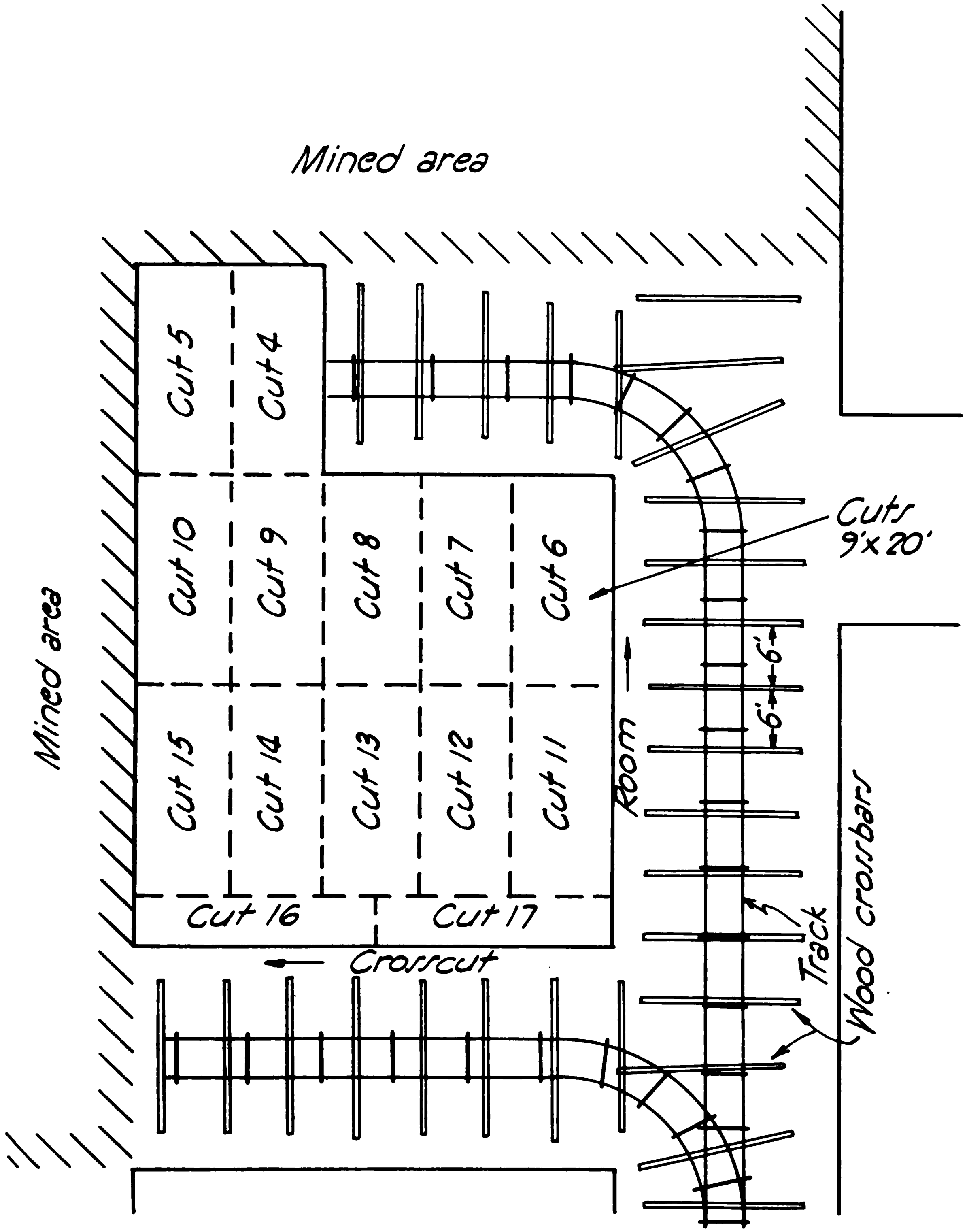


Figure 29. - Timbering details and cutting sequence in pillars at mine 62.

A mechanized unit crew follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator and driller	1
Cutting-machine helper and driller	1
Shot firer	1
Motorman	1
Brakeman	1
Timbermen	3
Trackman and helper	2
Foreman	1
Total	13

The cycle of operation follows:

1. Timber.
2. Lay track.
3. Drill and cut.
4. Charge and blast.
5. Load coal.

1. Timber. - All places are timbered with wood crossbars about 15 feet long and spaced 6 feet apart. Timbers are seldom recovered. An average of 25 tons of coal is produced per crossbar and 12.5 tons per crossbar leg.

2. Lay track. - Track is extended as close to the face as possible. Wood ties, steel ties, and 40-pound rails are used.

3. Drill and cut. - The two-man cutting and drilling crew drills five holes spaced about 4 feet apart near the bottom of the coal bed and four holes spaced 5 feet apart near the top of the bed. Holes are drilled with hand-held electric auger drills. A horizontal cut is then made about 3-1/2 feet above the bottom of the bed. Track-mounted arcwall cutting machines, equipped with 9-foot cutter bars, are used. At one of the mines, where the coal is about 6 feet thick, the rash above the coal does not adhere to the roof rock. At this mine, the coal is cut with a slabbing machine immediately below the rash. The rash is then raked from the cut with the cutter bar and loaded separately.

4. Charge and blast. - Each bottom hole is charged with four or five cartridges of permissible explosive and the charges in the five holes are detonated at the same time. After the broken coal below the cut has been loaded, each top hole is charged with three cartridges of permissible explosive, which is detonated four holes at a time. About 2.5 tons of coal are produced per pound of explosive.

5. Load coal. - Broken coal is loaded into 3-1/2-ton mine cars with track-mounted mobile loading machines. Mine cars are spotted for loading with cable-reel electric trolley locomotives. Loaded trips of 10 to 15 cars are transported to partings on the main haulage road outside the mine. These loaded coal trips are gathered and transported on the surface to the head house by main-line locomotives. Two 11-ton skips, operated from a balanced hoisting drum, transport the coal down a 30-degree double-tracked incline to the tipple.

Roof Action

Crossbars spaced about 6 feet apart in all working places support the rash and overlying weak shale during mining. In pillar mining, the roof shears at or near the cave line. Roof falls are high, and the entire overburden subsides as pillar mining progresses. Many vertical fissures and fractures are present in the overlying strata before the coal is mined. Many of these fissures are filled with clay, which can be seen on the sides of large pieces of caved rock in the gob areas. The roof caves readily along pillar lines and squeezes seldom occur.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	6	6	1	13
Loading-machine helpers	6	6	1	13
Cutting-machine operator-drillers	6	6	1	13
Cutting-machine helper-drillers	6	6	1	13
Shot firers	6	6	1	13
Motormen	6	6	1	13
Brakemen	6	6	1	13
Timbermen	15	15	3	33
Trackmen and helpers	13	13	2	28
Foremen	6	6	1	13
Total	76	76	13	165
Other underground employees:				
Motormen	6	6	2	14
Brakemen	6	6	2	14
Electricians (maintenance men)	6	6	2	14
Haulage maintenance (trackmen and timbermen)	17	-	-	17
Wiremen	2	-	-	2
Ventilation men	3	-	-	3
Drainage men	-	-	2	2
Dispatchers	1	1	-	2
Foremen	2	-	-	2
Total	43	19	8	70
Total underground employees	119	95	21	235
Surface employees:				
Tipplemen	11	11	-	22
Hoisting engineers	1	1	-	2
Car droppers	5	5	-	10
Shopmen	5	-	-	5
Car repairmen	5	-	-	5
Lamp men	1	1	1	3
Truck drivers	2	2	-	4
Weighmen	1	1	-	2
Carpenter	1	-	-	1
Foremen	2	2	-	4
Total	34	23	1	58

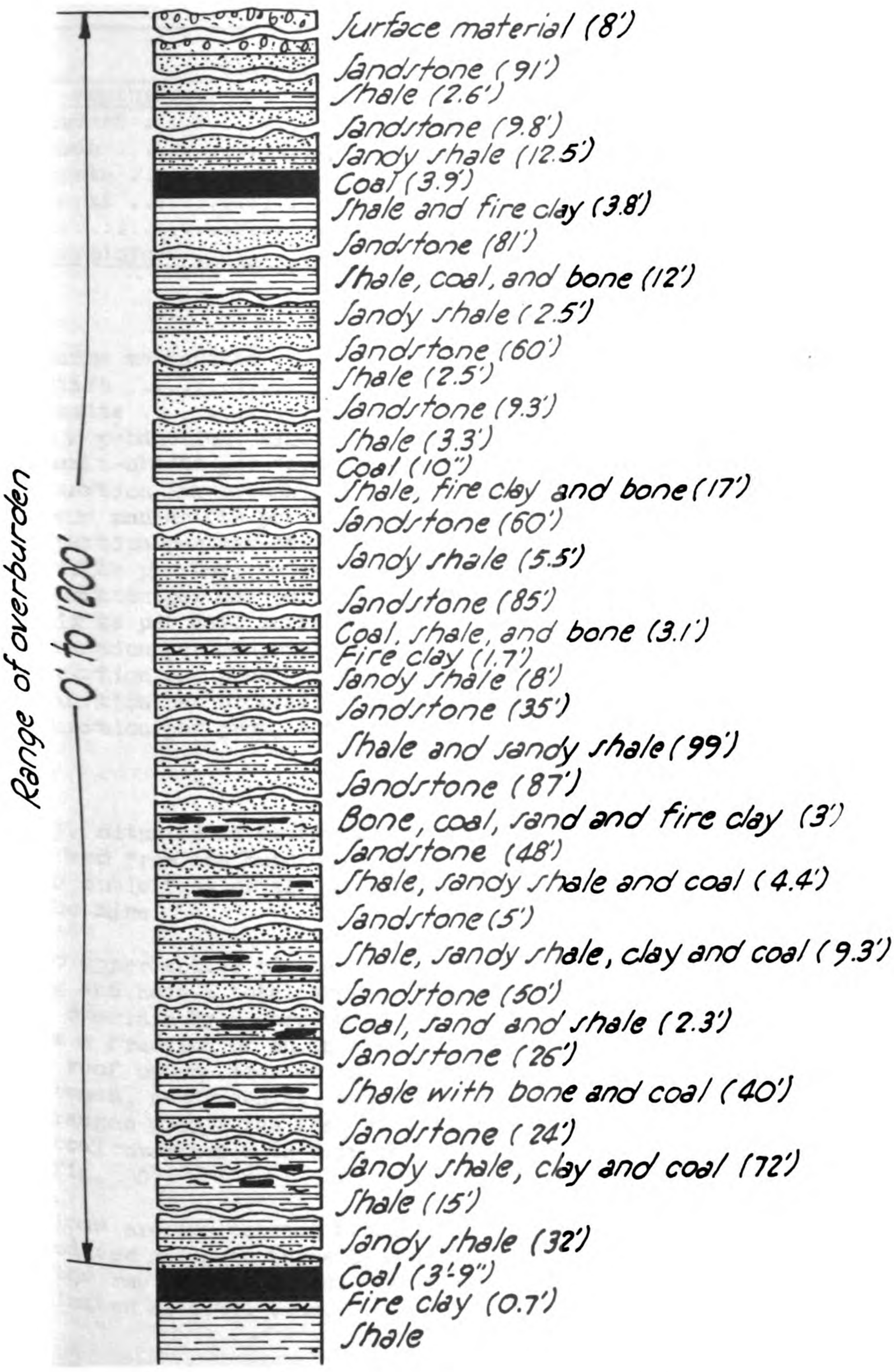


Figure 30. - Section of overburden and coal bed at mine 63.

Classification	Shift			Total
	1st	2d	3d	
Supervisory employees:				
Superintendent	1	-	-	1
Mine foremen	1	1	-	2
Office clerks	4	-	-	4
Supply clerks	1	1	-	2
Total	7	2	-	9
Total employees	160	120	22	302

Summary

Percent of mine mechanized	100
Hours per shift	8
Mechanized units	6
Average daily production, mine, tons	2,700
Mechanized unit-shifts per day	13
Average production per mechanized unit, per shift, tons	207.7
Average number man-shifts per day, mechanized units	165
Average production per man-shift, mechanized units, tons	16.4
Total man-shifts per day, underground	235
Average production per man per day, underground, tons	11.5
Total man-shifts per day, surface and underground	302
Average production per man employed, tons	8.9
Average production per pound of explosive, tons	2.5
Average production per crossbar, tons	25.0
Average production per prop, tons	12.5

Mine 63

Mine 63, situated in southwestern West Virginia, is opened by six drifts driven in the coal bed from the outcrop. Two ventilating fans, operated exhausting, furnish 220,000 cubic feet of air per minute, which is circulated through eight air splits in the mine.

The two upper splits of the Cedar Grove coal bed, which are separated by a thin bone parting and have a total average thickness of 45 inches in the area, are mined. The coal is overlain by a stratum of hard, sandy shale. A soft shale,draw slate, ranging from a fraction of an inch to 18 inches, is present between the coal and sandy shale roof on one side of the mine. The remaining overburden is comprised of thick sandstones, sandy shales, shales, and thin coal beds. The thickness of the overburden ranges from a few feet at the outcrop to 1,200 feet under the mountain tops. The coal overlies 6 to 8 inches of fire clay. The fire clay is underlain by shale (see fig. 30).

Operations are 100 percent mechanized, and an average of 3,666 tons of clean coal are produced daily in three 8-hour shifts. The yield of clean coal is about 82 percent of the raw coal produced. Therefore, the average daily production of raw coal is estimated at 4,471 tons.

Mining Method

The mine was opened during the first world war. The block system of mining is followed and pillars are extracted. The mine is developed by multiple main, cross (butt entries), and panel entries, which usually are driven to coal outcrops or property boundaries before extraction begins. Main entries are driven in sets of six or seven on 60-foot centers (see fig. 31). Cross entries are turned at right angles off main entries 1,600 to 1,800 feet apart and are driven in sets of four on 60-foot centers. Panel entries are turned at right angles off one side of the cross entries on about 460-foot centers and are driven in sets of four on 70-foot centers 1,600 to 1,800 feet to boundaries or until they encounter another set of cross entries. Rooms are turned at right angles on 70-foot centers off one side of panel entries and are mined on retreat. Rooms average about 240 feet deep and are usually limited in length by boundaries or caved areas of adjacent panels. All entries, rooms, and crosscuts are driven 20 feet wide. The regional dip of the coal bed is 2 percent southwest. Rolls producing grades up to 10 percent occur locally. Cleats in the coal and roof are not pronounced and do not affect the plan of development.

At the time of this study, five mobile loading units were engaged in developing rooms and crosscuts and in extracting room and panel-entry pillars. Five units were engaged in entry development and mining of rooms on narrow centers where conditions do not favor pillar extraction.

A mobile loading unit constitutes 12 men, 1 mobile loading machine, 1 cutting machine, 1 coal drill, 2 shuttle cars, 1 elevating conveyor, and 1 car hoist.

Pillar Extraction

During the calendar year preceding this study, 63.5 percent of the production was from entry development; 16.0 percent from room development; and 20.5 percent from pillar mining. About 45 percent of the coal produced from panels where pillars are extracted is from entries, rooms, and crosscuts and 55 percent from pillars.

Each panel is 460 feet wide and 1,600 to 1,800 feet long. After panel entries have been developed, rooms are started at the inby end of the panel. Five rooms are under development at a time and are advanced so that the working faces are on a line forming a 30-degree angle with the entries (rooms 8, 9, 10, 11, and 12, fig. 32). At the same time, room pillars between preceding rooms and entry chain pillars are extracted (pillars 1 to 8, fig. 32). These pillars are mined in the order shown (1 to 8) to form a cave line, "X-X" 60 degrees with the entries. After all or part of pillars 1 to 8 have been extracted, room 8 has been completed and room 13 begun. Then mining of pillars along line "Y-Y" begins.

Room pillars are blocks 50 feet wide and 60 feet long. Entry chain pillars are blocks 50 feet wide and 40, 70, or 85 feet long. The open-end system of pillar extraction is followed. Lifts are 25 feet wide, and only one lift is worked at a time. (See alphabetical sequence of lifts, fig. 32.) If roof conditions are bad, a small stump of coal is left between the gob and the first cut in the lift. This stump is partly recovered after the lift has been completed.

Pillar lines seldom extend across more than one panel. When retreat mining in a panel reaches the cross entries from which the panel was driven, pillar mining is continued across the cross entries and into a panel developed from an adjacent outby set of cross entries. Mine-car haulage is then changed to pass through the outby cross entries.

A mechanized unit crew follows:

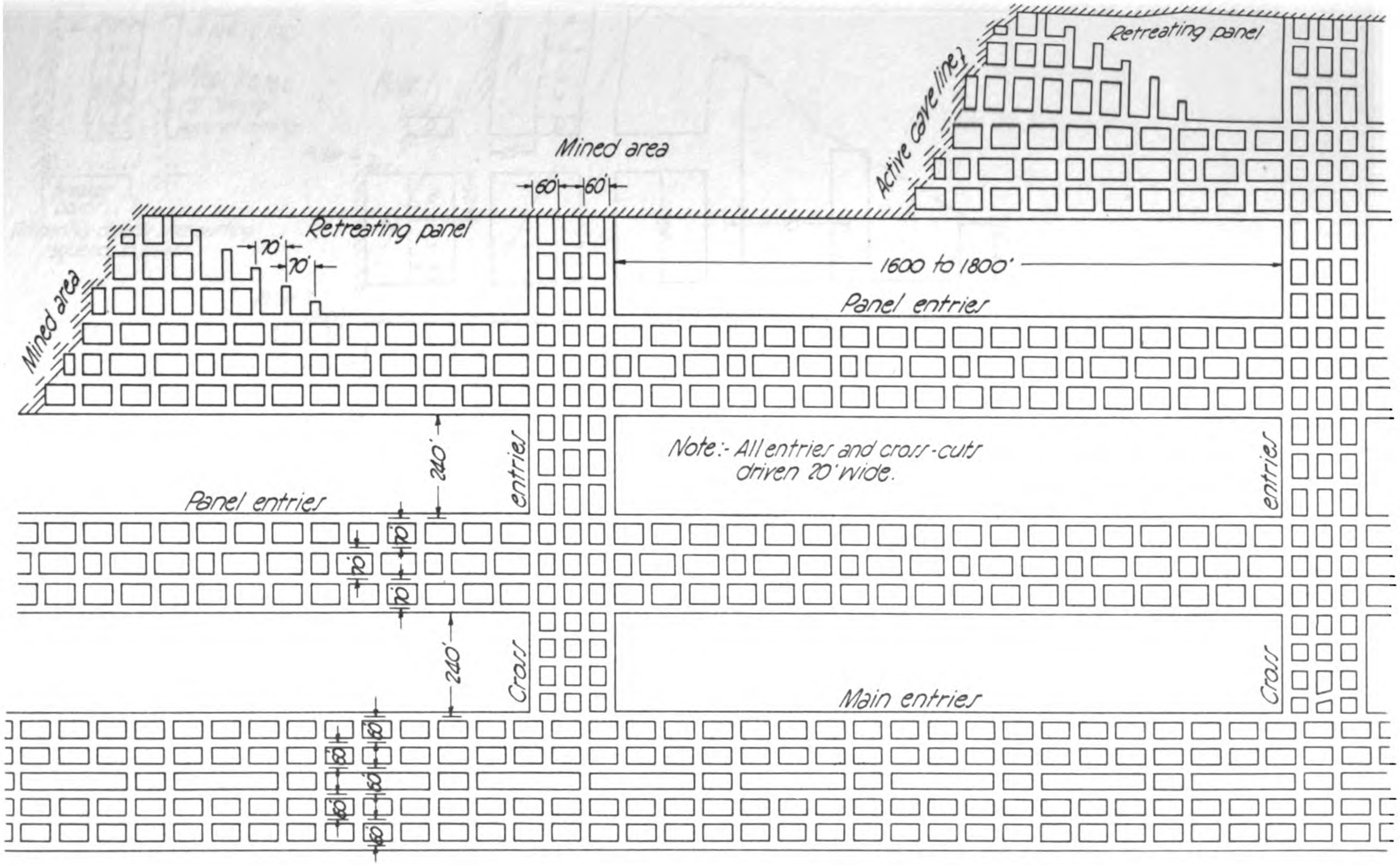


Figure 31. - Mining method at mine 63.

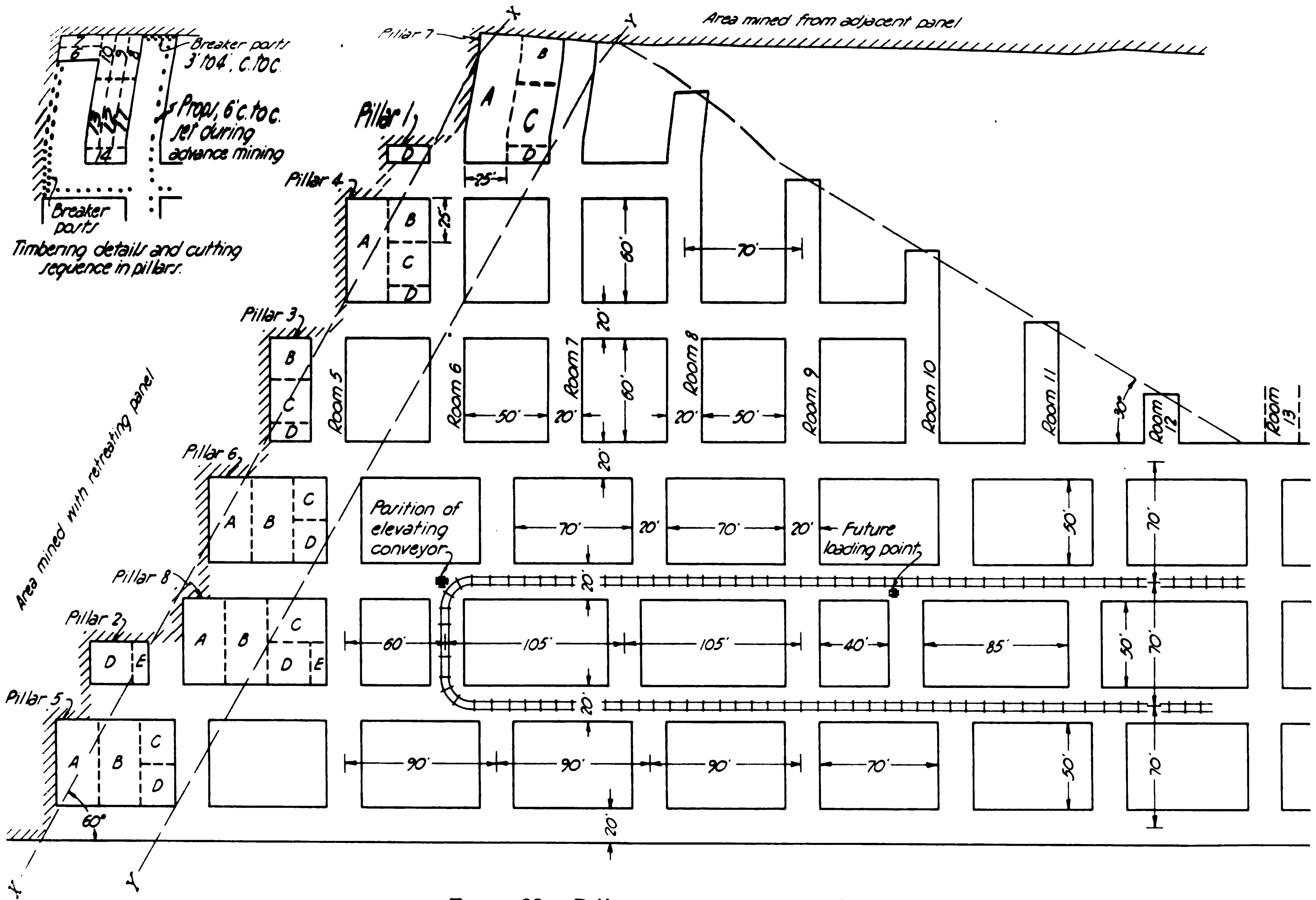

Breaker posts 3' to 4', C. to C.
Props, 6' c. to c. set during advance mining
Breaker posts
Timbering details and cutting sequence in pillars.
Area mined from adjacent panel
Area mined with retreating panel
Pillar 1
Pillar 2
Pillar 3
Pillar 4
Pillar 5
Pillar 6
Pillar 7
Pillar 8
A
B
C
D
E
X
Y
Room 5
Room 6
Room 7
Room 8
Room 9
Room 10
Room 11
Room 12
Room 13
Position of elevating conveyor
Future loading point
25'
60'
70'
50'
20'
30'
105'
40'
85'
90'
60°

Figure 32. - Pillar extraction at mine 63.

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Shuttle-car operators	2
Driller	1
Shot firer	1
Timberman (rock duster)	1
Car hoist-elevating conveyor operator	1
Repairman	1
Foreman	1
Total	12

The cycle of operation follows:

1. Timber.
2. Cut.
3. Drill.
4. Charge and blast.
5. Load coal.

1. Timber. - During advance mining, one or two rows of props are set on 4-foot centers along one side of all places as the coal faces are advanced. In pillar mining, two to three rows of breaker posts are set 3 or 4 feet apart along the gob side of lifts to aid in breaking the roof (see timbering details in pillars, fig. 32). An average of 12.7 tons of raw coal is produced per prop. Crossbars are used, where necessary. In some small areas where the draw slate over the coal is more than 15 inches thick, the roof is bolted. In these areas, rooms are driven on narrow centers and pillars are not extracted.

2. Cut. - The coal is bottom cut with crawler-mounted, arcwall cutting machines equipped with 9-foot cutter bars.

3. Drill. - Four holes usually are drilled per cut about 5 feet apart near the top of the coal bed. The holes are drilled with an electric auger-type drill mounted on shortwall cutting machine trucks. Drilling is done by one man.

4. Charge and blast. - Holes are charged with three cartridges of permissible explosive, which is detonated electrically one hole at a time. Production per pound of explosive is estimated at 6.6 tons, raw coal.

5. Load coal. - Coal is loaded into cable-reel shuttle cars of 3-ton capacity with crawler-mounted mobile loading machines. Shuttle cars transport the coal to an elevating conveyor at the U-turn on the panel haulage track. Mine cars of 4-ton capacity are spotted for loading at the elevating conveyor with a car hoist. Trips of loaded mine cars are transported to the surface by two trolley locomotives coupled in tandem.

Roof Action

The thin stratum of draw slate, where present over the coal bed, must be supported with timbers or taken down. The thick stratum of sandy shale, which overlies the coal bed and the draw slate, usually is strong enough to support itself during advance mining. In pillar mining, the roof caves by shearing at or near the breaker posts. Caving generally follows pillar mining closely. Caves in the gob area are high, and surface cracks are known to appear as much as 700 feet above the coal bed. At this mine, the roof generally is much stronger than the immediate fire clay bottom. Because of this, the bottom often breaks and heaves in rooms and entries near the cave line. Apparently, there is no difference in roof action under thin or thick overburden.

Recovery

The coal bed at this mine occurs in four splits or benches. The two upper splits occur together, sometimes separated by a thin parting. Only this part of the bed is mined. The third split, while equally as persistent, is more than 4 feet below the two upper splits and is not mined. Pillar extraction is practiced in all areas of the mine except in some small areas where the draw slate is more than 15 inches thick and in areas under stream beds. Pillars are left under streams to keep the roof from breaking and to prevent surface water from entering the mine. Recovery in panels is estimated at 80 percent and over-all mine recovery at nearly 70 percent of the part of the bed mined.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	10	10	1	21
Loading-machine helpers	10	10	1	21
Cutting-machine operators	10	10	1	21
Cutting-machine helpers	10	10	1	21
Shuttle-car operators	20	20	2	42
Drillers	10	10	1	21
Shot firers	10	10	1	21
Timbermen (rock dusters)	10	10	1	21
Car hoist-elevating conveyor operators	10	10	1	21
Repairmen	10	10	1	21
Foremen	10	10	1	21
Total	120	120	12	252
Other underground employees:				
Motormen	12	12	-	24
Brakemen	12	12	-	24
Trackmen	11	7	-	18
Slatemen	6	-	-	6
Ventilation men	5	-	-	5
Maintenance men	12	-	-	12
Timbermen	4	-	-	4
Rock dusters	-	-	4	4
Supply men (3 motormen, 3 brakemen)	-	-	6	6
Dust suppression man	1	-	-	1
Dispatchers	1	1	1	3
Foremen	5	1	-	6
Total	69	33	11	113
Total underground employees	189	153	23	365

Classification	Shift			Total
	1st	2d	3d	
Surface employees:				
Tipplemen	23	21	3	47
Tipple foremen	1	1	-	2
Shopmen and repairmen	4	4	13	21
Bonders and wiremen	5	2	2	9
Car repairmen	3	-	-	3
Blacksmith	1	-	-	1
Welder	1	-	-	1
Lamp men	1	1	1	3
Shop foremen	1	1	1	3
Total	40	30	20	90
Supervisory employees:				
Superintendent	1	-	-	1
Assistant superintendent	1	-	-	1
Mine foremen	1	1	1	3
Assistant mine foremen	1	1	-	2
Clerk	1	-	-	1
Total	5	2	1	8
Total employees	234	185	44	463

Summary

Percent of mine mechanized	100
Hours per shift	8
Average yield, clean coal from raw coal, percent	82
Mechanized units	10
Mechanized unit-shifts per day	21
Average number man-shifts per day, mechanized units	252
Total man-shifts per day, underground	365
Total man-shifts per day, surface and underground	463
Recovery, panels, percent	80
Recovery, mine, percent	70

	Raw coal[1/]	Clean coal
Average daily production, mine, tons	4,471	3,666
Average production per mechanized unit per shift, tons	213	175
Average production per man-shift, mechanized units, tons	17.7	14.5
Average production per man per day, underground, tons	12.2	10.0
Average production per man employed, tons	9.7	7.9
Average production per pound of explosive, tons	6.6	5.4
Average production per prop, tons	12.7	10.4

[1/] Raw coal includes all material sent to tipple.

Mine 64

Mine 64, situated in northern West Virginia, is opened by six drifts driven in the coal bed from the outcrop. One ventilating fan, operated exhausting, furnishes 75,000 cubic feet of air per minute through one continuous circuit in the mine.

The Pittsburgh coal bed, which ranges from 5 to 9 feet thick and averages 7 feet thick in the area, is mined. The coal is overlain by 8 to 20 feet of soft claystone, locally called soapstone, which deteriorates upon exposure to the air. Because of this, 12 to 18 inches of coal are left for roof. The claystone is overlain by a bed of limestone, which ranges from 4 to 25 feet thick. The remaining overburden consists of shales and shaly sandstones (see fig. 33). The thickness of the overburden ranges from a few feet at the outcrop to 250 feet under the hilltops. The coal is underlain by a thick stratum of fire clay.

Operations are 100 percent mechanized, and 1,000 tons of raw coal are produced in two 8-hour shifts.

Mining Method

The mine was opened in July 1948. The block system of mining is followed and pillars are extracted. The mine is developed by multiple main and panel entries driven 18 feet wide on 60-foot centers (see fig. 34). Where possible, entries are driven in sets of 15 with crosscuts at intervals of 90 feet. One panel was being mined at the time of this study. Mining was on retreat and only ten entries had been completely developed because of poor mining conditions and the danger of surface water from a stream on one side of the panel. The regional dip of the coal bed is 3 percent northwest. Cleats in the coal are pronounced but do not influence the plan of development. Barrier pillars, 200 feet square, are left around gas wells.

Panels are driven to outcrops or predetermined limits. At the time of this study, one mobile loading unit was engaged in extracting pillars in the panel that had already been developed. The mobile loading unit is comprised of 15 men, 1 mobile loading machine, 1 cutting machine, 1 coal drill, 2 shuttle cars, 1 belt conveyor, 1 portable air compressor, 1 stoper-type pneumatic drill, and 1 pneumatic impact wrench.

Pillar Extraction

At the time of this study, the entire production was from pillar mining. About 45 percent of the portion of the bed mined in the panel had been mined during development.

The panel was about 560 feet wide and 2,000 feet long. Entry crosscuts on one side of the belt entry were developed in a line to form rooms leading from the belt entry. Pillars of coal are 42 feet wide and 72 feet long, except in the row on each side of the belt entry where they are 27 feet wide. The pillars are mined to form a straight pillar line across all the entries and perpendicular to the belt conveyor.

Lifts, 18 feet wide, are driven to the right across the inby ends of pillars. A fender, 6 feet wide, is left on the gob side of lifts. This fender is cut through on the third cut and is blasted after the lift has been completed (see fig. 35). The cutting cycle follows along the entire pillar line as the panel retreats. For example, one cut is made in corresponding lifts in pillars A to J (fig. 34) during each cutting cycle. In this way, mining of pillars A to J is completed at about the same time.

A mechanized unit crew follows:

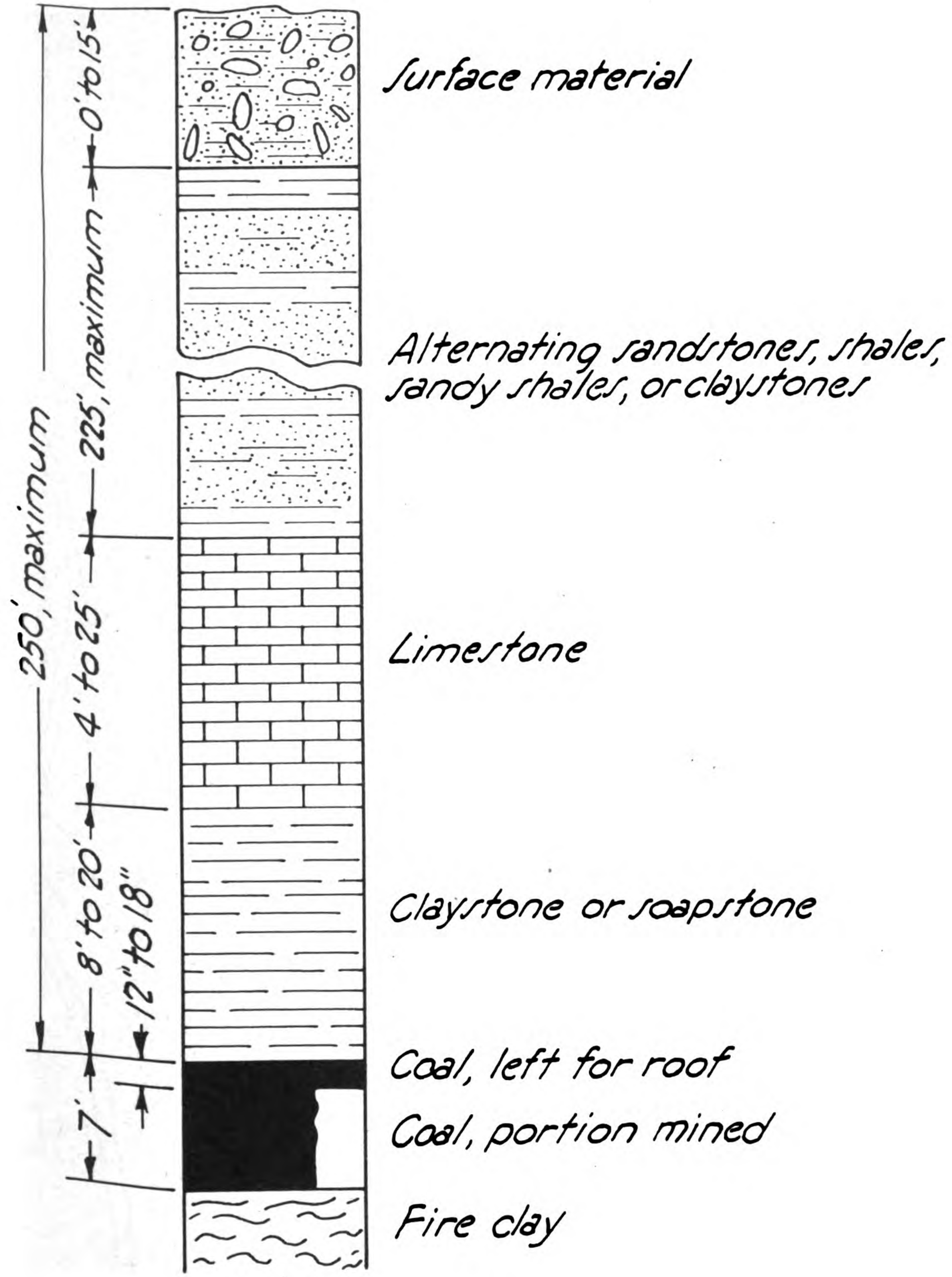


Figure 33. - Section of coal bed and overburden at mine 64.

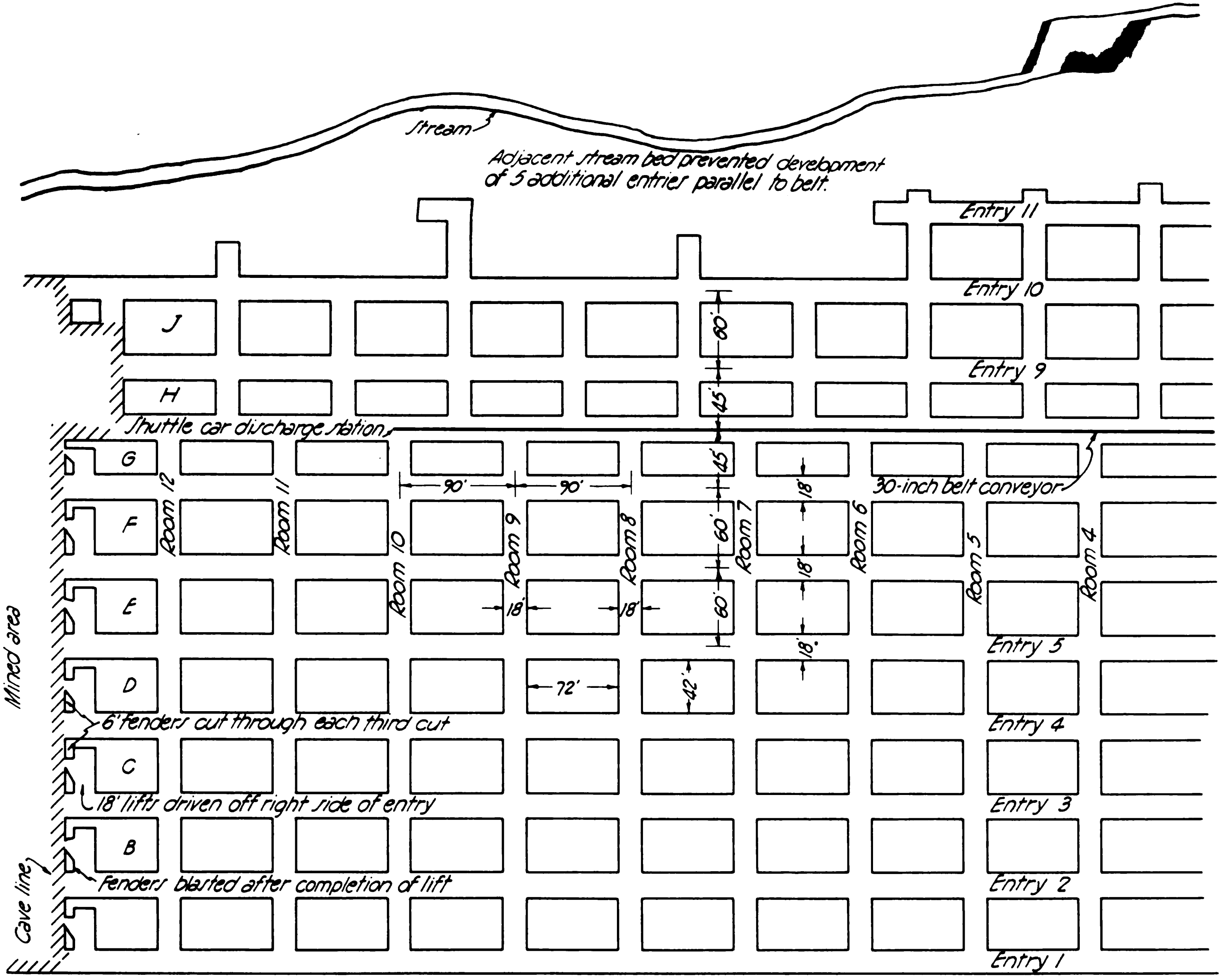

Stream
Adjacent stream bed prevented development of 5 additional entries parallel to belt.
Entry 11
Entry 10
Entry 9
J
H
Shuttle car discharge station
G
F
E
D
C
B
30-inch belt conveyor
Room 12
Room 11
Room 10
Room 9
Room 8
Room 7
Room 6
Room 5
Room 4
90'
90'
60'
45'
45'
60'
60'
18'
18'
18'
18'
18'
18'
72'
42'
Entry 5
Entry 4
Entry 3
Entry 2
Entry 1
Mined area
Cave line
6' fenders cut through each third cut
18' lifts driven off right side of entry
Fenders blasted after completion of lift

Figure 34. - Mining method at mine 64.

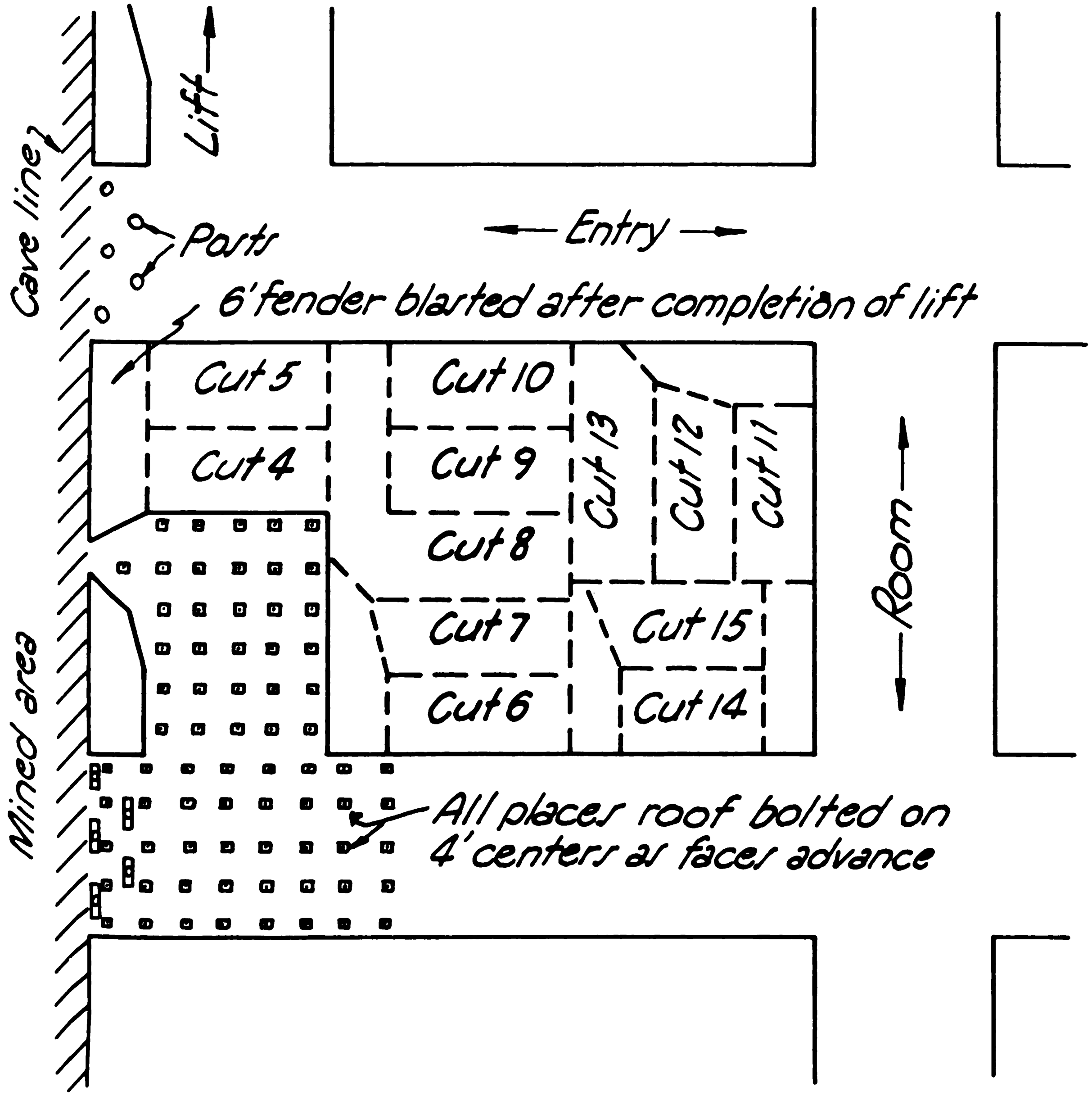


Figure 35. - Pillar extraction and roof-support method at mine 64.

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator	1
Cutting-machine helper	1
Driller-shot firers	2
Shuttle-car operators	2
Roof bolting crew	4
Extra men	2
Foreman	1
Total	15

The cycle of operation follows:

1. Bolt roof and timber.
2. Cut.
3. Drill.
4. Charge and blast.
5. Load coal.

1. Bolt roof and timber. - All working places are roof bolted to the face as the places are advanced. Slit-rod-and-wedge-type bolts are installed on 4-foot centers to within about 2 feet of the ribs. An assembly for bolting the roof consists of one steel rod, 1 inch in diameter and 60 inches long; one steel wedge, 3/4 by 3/4 by 5-1/2 inches long; one 8- by 8- by 3/8-inch steel bearing plate; and one hexagonal nut. Bolt holes are drilled vertically, and the bolts are seated over the wedge with a stoper-type pneumatic drill. Nuts are tightened to about 250-foot-pounds torque with a pneumatic impact wrench. A 250-cubic feet per minute air compressor, mounted on a converted timbering machine, supplies compressed air to the pneumatic tools. Safety jacks are used at the face during roof-bolting installations. Props are used at the cave line. Props and bolts are not recovered. The roof bolting and timbering diagram is shown in figure 35. About 4.5 tons of coal are produced per bolt.

2. Cut. - The coal is top cut with a rubber-tired universal-type cutting machine equipped with a 9-foot cutter bar. One vertical shear cut is made at the right rib during advance mining. The left rib or gob side of lifts are sheared in pillar mining.

3. Drill. - Three or four holes are drilled near the bottom of the coal bed. The holes are drilled with a hand-held electric auger-type drill.

4. Charge and blast. - Holes are charged with three or four cartridges of permissible explosive, which is detonated electrically, one hole at a time. A crew of two men drill, charge, and blast the coal. Production per pound of explosive is estimated at 4.0 tons.

5. Load coal. - Coal is loaded into 4-1/2-ton cable-reel shuttle cars with crawler-mounted mobile loading machines. Shuttle cars transport the coal to the inby end of the panel belt conveyor and discharge directly onto the belt. The panel belt conveyor discharges the coal onto a belt conveyor in the main entry. The mainline belt conveyor transports the coal to the surface. The panel belt and the main belt are each 30 inches wide.

Roof Action

The roof coal and overlying soft claystone or soapstone break and cave readily as pillars are extracted and the cave line retreats. Initial roof falls are usually thick pieces held together by the roof bolts. The limestone strata overlying the shale does not cave readily and often spans large areas. This condition sometimes causes squeezes with the result that the soft fire-clay bottom heaves and interrupts the regular order of pillar extraction. In extreme cases, the pillar line is abandoned and another started one or two rooms outby the original cave line. Much water is encountered during pillar extraction near stream beds.

Roof bolting appears to be effective in providing better working height as well as better roof support at this mine. The number of premature roof falls and the amount of rock loaded from roof falls have been greatly decreased since roof bolting was begun. Since the mine has no facilities for transporting rock to the surface and little room for gobbing rock inside the mine, roof bolting has a decided advantage over conventional timbering. The volume of materials and supplies transported from the surface to the underground working faces by battery-powered shuttle cars has been decreased. Roof bolts have replaced nearly all three-piece timber sets previously installed 3 to 5 feet apart in all working places as the coal faces were advanced.

Wood props are still used for safety in entries at the cave line, and in other places, where necessary. The increase in cost of roof supporting materials per ton of coal has been offset by an increase in production of coal.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	1	1	-	2
Loading-machine helpers	1	1	-	2
Cutting-machine operators	1	1	-	2
Cutting-machine helpers	1	1	-	2
Driller-shot firers	2	2	-	4
Shuttle-car operators	2	2	-	4
Roof bolting crew	4	4	-	8
Extra men	2	2	-	4
Foremen	1	1	-	2
Total	15	15	-	30
Other underground employees:				
Drainage men	2	1	-	3
Supplies crew	2	-	-	2
Belt men	2	2	-	4
Ventilation man	1	-	-	1
Mechanic-electricians	1	1	2	4
Wireman	1	-	-	1
Fire boss	-	-	1	1
Foreman	1	1/2	-	1-1/2
Total	10	4-1/2	3	17-1/2
Total underground employees	25	19-1/2	3	47-1/2
Surface employees:				
Lamp men	1/2	1/2	-	1
Mechanic	1	-	-	1
Blacksmith	1	-	-	1
Truck mechanic	1/3	-	-	1/3
Tipplemen	3	2-2/3	2/3	6-1/3
Truck drivers	1-2/3	1-2/3	-	3-1/3
Tipple foreman	1/3	1/3	-	2/3
Total	7-5/6	5-1/6	2/3	13-2/3

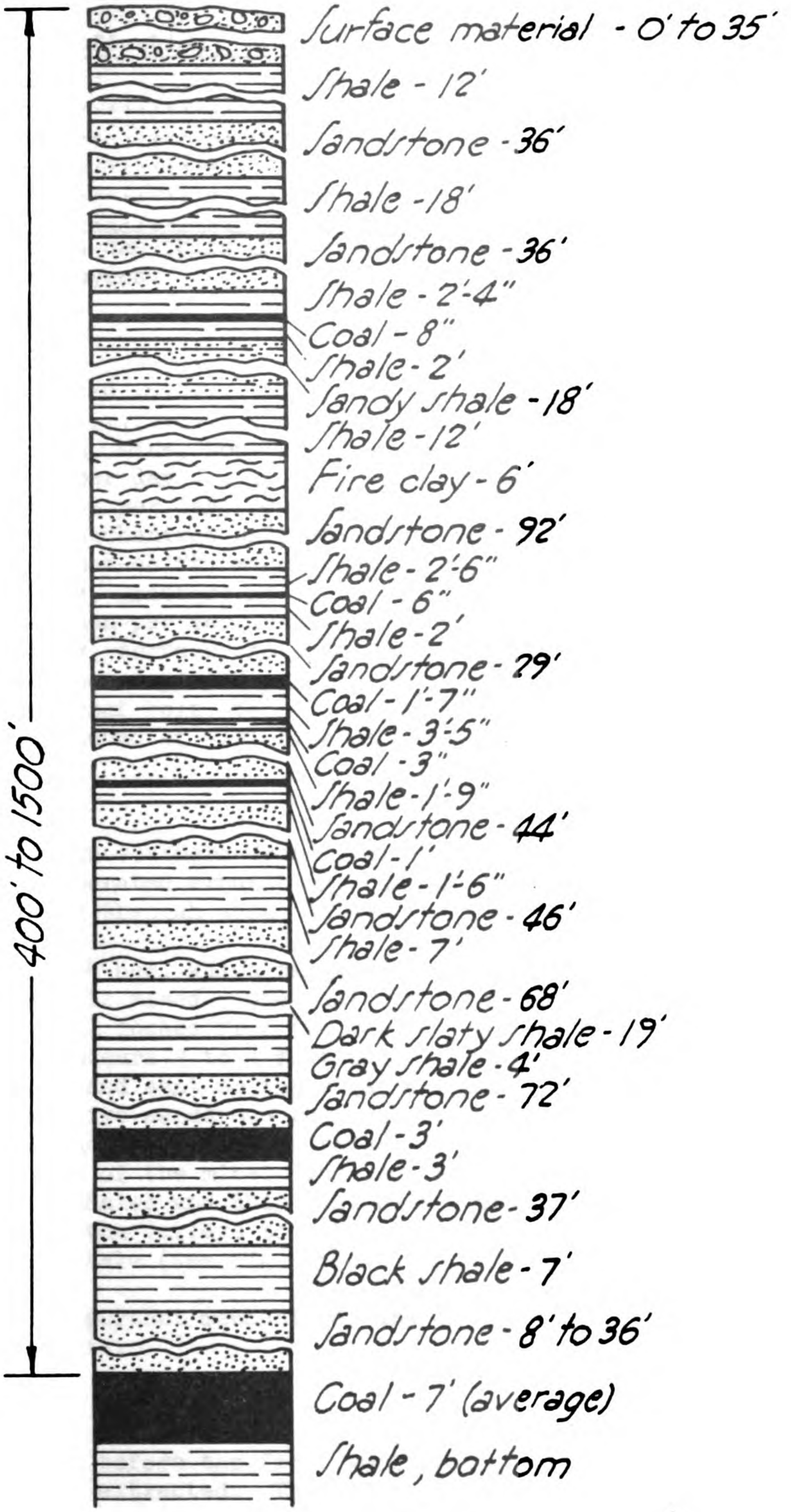


Figure 36. - Section of overburden and coal bed at mine 65.

Classification	Shift			Total
	1st	2d	3d	
Supervisory employees:				
Superintendent	1/2	-	-	1/2
Supply clerk	1/3	1/3	-	2/3
Office clerk	1/3	1/3	-	2/3
Total	1-1/6	2/3	-	1-5/6
Total employees	34	25-1/3	3-2/3	63

Note: The mine produces one-third of the coal charged to surface employees and supervisory employees.

Summary

Percent of mine mechanized	100
Hours per shift	8
Average daily production, mine, tons	1,000
Mechanized unit-shifts per day	2
Average number man-shifts per day, mechanized units	30
Average production per mechanized unit-shift per day, tons	500
Average production per man-shift, mechanized units, tons	33.3
Total man-shifts per day, underground	47-1/2
Average production per man per day, underground, tons	21.1
Total man-shifts per day, surface and underground	63
Average production per man employed per day, tons	15.9
Average production per roof bolt, tons	4.5
Average production per pound of explosive, tons	4.0

Mine 65

Mine 65, situated in southern West Virginia, is opened by six vertical shafts. Two ventilating fans, operated exhausting, furnish 800,000 cubic feet of air per minute, which is circulated through about 30 air splits in the mine.

The Pocahontas No. 4 bed, which ranges from 6 to 8 feet thick and averages 7 feet thick in the area, is mined. One shale parting, as much as 2 inches thick, sometimes occurs about 12 inches from the top of the coal bed. A 3- to 4-inch band of splint coal usually occurs 3 to 4 feet below the top of the bed. Both partings are mined with the coal and sent to the cleaning plant. The coal is overlain by a stratum of flaky to massive sandstone that ranges from 8 to 36 feet thick. A soft shale, draw slate, as much as 12 inches thick, is present between the coal and sandstone roof in some areas of the mine. The remaining overburden consists of thick beds of sandstones and shales and thin coal beds. The thickness of the overburden ranges from 400 feet in the valleys to 1,500 feet under the mountain tops. The coal is underlain with firm shale (see fig. 36).

Operations are 100 percent mechanized, and 4,700 tons of raw coal are produced daily in two 8-hour shifts.

Mining Method

The mine was opened before the first world war. The block system of mining is followed and pillars are extracted. The mine is developed by multiple main and panel entries. Main entries are driven in sets of 6 to 10 on 75-foot centers with crosscuts on 90-foot centers. Panel entries are driven at right angles off main entries in sets of four to six on 90-foot centers with crosscuts on 75-foot centers.

Rooms are driven at right angles off panel entries on 75-foot centers with crosscuts on 90-foot centers. Entries, rooms, and crosscuts are driven 18 feet wide (see fig. 37). Panel entries are driven to predetermined limits or to want areas before pillar extraction begins. Panels are usually 1,080 feet or 12 blocks wide. Barrier pillars, 900 feet wide, separate the main entries from outby rooms in panels. Want areas in which all or part of the coal has been replaced with rock are encountered frequently. These want areas are sometimes several miles long and as much as 1,000 feet wide.

The regional dip of the coal bed is about 2 percent northwest. Dips producing grades up to 5 percent occur locally. Cleats in the coal and roof are not pronounced and do not influence the plan of development.

Coal is produced with 18 mobile loading unit-shifts per day. Loading-machine units usually do not operate double shift in the same working places because of excessive liberation of methane gas. Cutting and drilling units are operated separately from loading-machine units, and usually do not work in the same area during the same shift. Ten cutting and drilling unit-shifts prepare the coal for the 18 loading unit-shifts.

Pillar Extraction

At the time of this study, about 65 percent of the coal produced was from pillar mining and 35 percent from entries, rooms, and crosscuts. About 60 percent of the coal produced in a panel is from entries, rooms, and crosscuts and 40 percent from pillars.

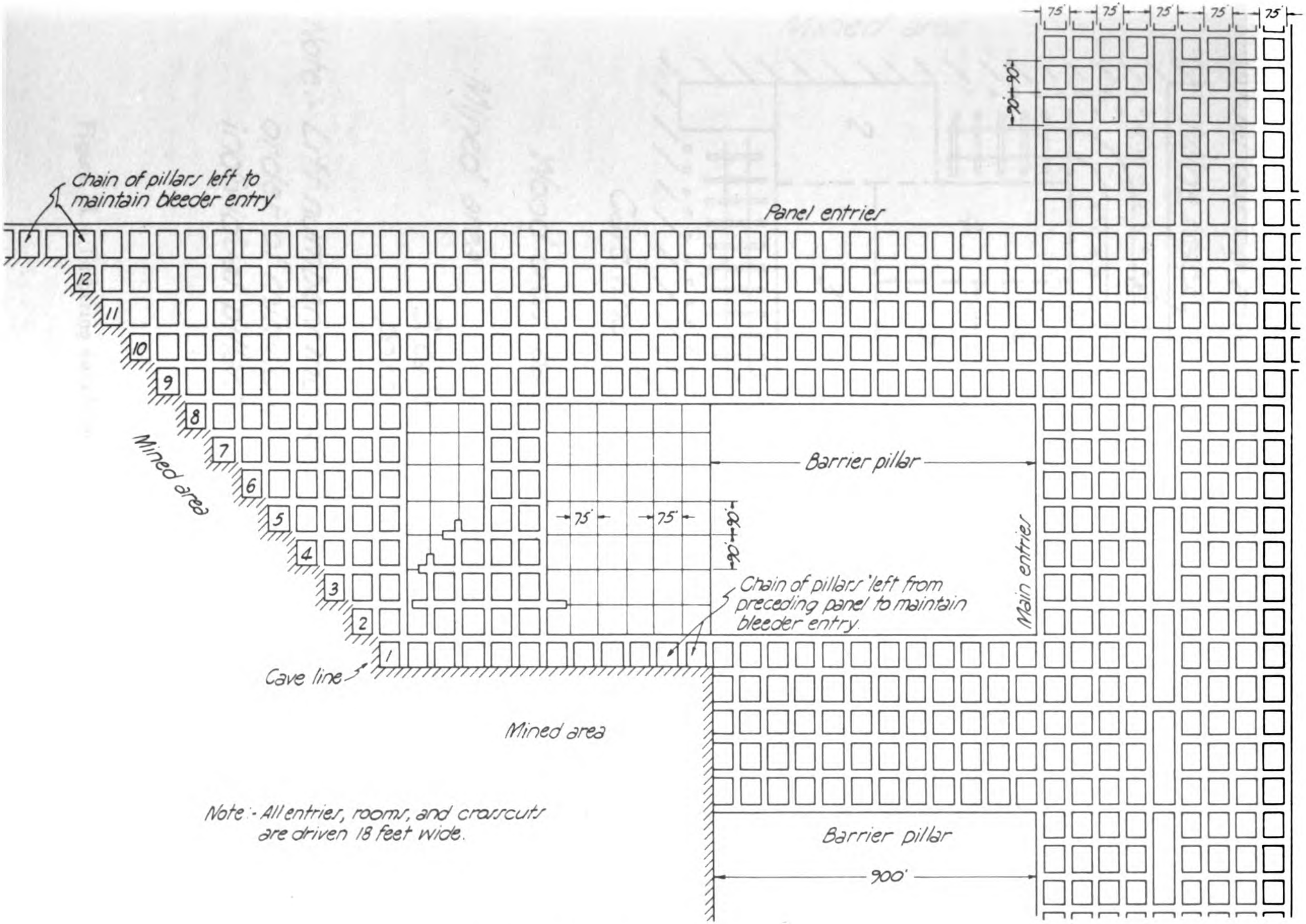
Each panel is usually 12 blocks, 1,080 feet wide. The length of panels is determined by property limits, mine layout, or the presence of want areas and ranges from 3,000 to 5,000 feet. Panel entries are driven to the limits before room development and pillar extraction begin. Pillars are mined in regular order to form a pillar line about 50 degrees to the entries (see fig. 37). Mining is conducted at the same time on all the pillars along the pillar line in the panel, but the cutting sequence is timed so that no two adjacent pillars are completed at the same time. By following this plan, concussions from large roof falls are minimized.

A pillar line consists of about 12 pillars, each 57 feet wide and 72 feet long. The open-end system of pillar extraction is followed. Lifts 18 feet wide are mined from two sides of a pillar at the same time. However, no two lifts in one pillar are completed at the same time but are completed in the numerical order shown in figure 38.

Two or three mobile loading units operate in one panel, although not always during the same shift. One unit mines pillars 1 to 6 (fig. 37); another, pillars 7 to 12; and a third unit develops rooms in advance of the cave line.

A single row of pillars is left at the outside boundary of all caved areas to provide a bleeder entry. As one panel is retreated, the row of pillars left during the mining of an adjacent panel is recovered. Active pillar lines seldom extend across more than one panel. Part of the return air in a panel passes through the bleeder entry and over caved areas.

The cycle of operation follows:



Note:- All entries, rooms, and crosscuts are driven 18 feet wide.

Figure 37. - Mining method at mine 65.

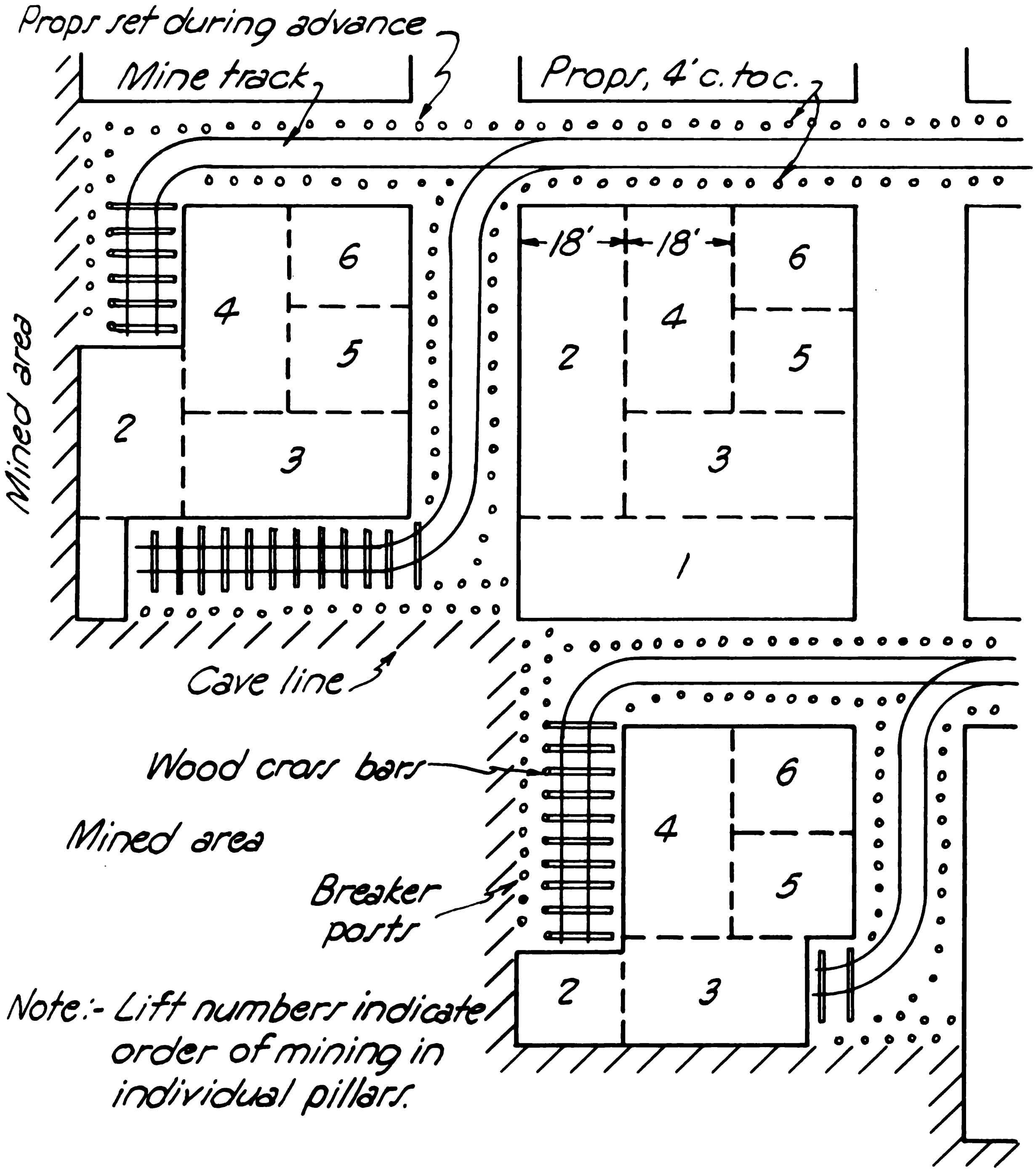


Figure 38. - Timbering details and sequence of lifts in pillars at mine 65.

1. Timber and extend curtain.
2. Lay track.
3. Cut.
4. Drill.
5. Charge and blast.
6. Load coal.

1. Timber and extend curtain. - During advance mining, one row of props is set on 4-foot centers along each side of the track as the coal faces are advanced. In pillar mining, wood crossbars are installed on 4-foot centers in lifts as the faces are advanced. One row of posts also is set on 4-foot centers on the gob side of lifts to aid in breaking the roof (see timbering details, fig. 38). Crossbars are used on roadways, where necessary. An average of 21.0 tons of raw coal is produced per crossbar and 4.5 tons per prop. Timbers are not recovered. Curtains for conducting air to the face inby the last open crosscut in all entries, rooms, and crosscuts are repaired and extended after each cut of coal is loaded.

2. Lay track. - Track is laid to the face before the coal is cut. Forty-pound rails and steel ties generally are used in panels.

3. Cut. - The coal is cut with track-mounted arcwall cutting machines equipped with 9-foot cutter bars. A horizontal cut is made about 3 feet above the bottom of the coal bed. Power for cutting is transmitted from a portable storage battery through a trailing cable.

4. Drill. - Six holes usually are drilled in the face, three at the top of the bed and three at the bottom. The holes are drilled with hand-held electric auger-type drills. Power for drilling is transmitted through a cable from a receptacle on the cutting machine.

5. Charge and blast. - Bottom holes are charged with two or three cartridges of permissible explosive, which is detonated electrically, one hole at a time. Top holes are then charged with one or two cartridges of explosive and fired in a similar manner. Production per pound of explosive is estimated at 6.4 tons, raw coal.

6. Load coal. - Coal is loaded into 4-ton mine cars with track-mounted mobile loading machines. A portable storage battery supplies electric power to the loading machine through a trailing cable. Mine cars are spotted at the loading machine with battery-powered locomotives. Trips of about 35 loaded mine cars are gathered and transported to the shaft bottom with battery-powered main-line locomotives.

Storage batteries for locomotives and mining equipment usually operate one shift before recharging becomes necessary. Therefore, most battery changes are made between shifts. Batteries are charged at permanent charging stations near the shaft bottom and are not used for more than one successive shift.

Roof Action

The sandstone stratum overlying the coal bed contains bedding planes at which the rock separates when the roof caves. Roof falls are in the form of large slabs with little vertical shearing at the breaker posts. Initial roof falls follow pillar mining closely, but the higher falls do not occur immediately. The large masses of caved rock form a gentle slope leading upward from the pillar line. The general subsidence of the overburden causes some crushing of the coal along the pillar line. Because of this crushing, loading machines are often able to load coal for several feet beyond the back of the cut during pillar mining. The shale stratum underlying the coal bed is firm and seldom heaves in areas along the cave line. Surface cracks occur over mined areas and areas being mined. Apparently, there is no difference in roof action under thin or thick overburden at this mine.

Classification of Employees

	Shift			
Classification	1st	2d	3d	Total
Mechanized units:				
Loading-machine operators	9	9	-	18
Loading-machine helpers	9	9	-	18
Cutting-machine operators	4	4	2	10
Cutting-machine helpers	4	4	2	10
Drillers	4	5	2	11
Timbermen and helpers	46	39	-	85
Trackmen and helpers	30	29	-	59
Shot firers	9	9	-	18
Motormen	15	17	-	32
Brakemen	20	20	-	40
Curtain and pipemen	8	9	-	17
Machine cut cleaners and clean-up men	14	10	-	24
Foremen	9	9	-	18
Total	181	173	6	360
Other underground employees:				
Motormen	4	4	3	11
Brakemen	4	4	3	11
Timbermen and helpers	9	6	4	19
Trackmen and helpers	7	5	2	14
Ventilation men	12	-	-	12
Drainage men	1	-	1	2
Rock dusters	-	-	4	4
Supply men	2	-	10	12
Maintenance and repairmen	15	7	13	35
Shaft bottom crew	4	4	-	8
Miscellaneous laborers	9	11	11	31
Dispatchers	1	1	1	3
Fire bosses	1	3	4	8
Foremen	3	3	3	9
Total	72	48	59	179
Total underground employees	253	221	65	539
Surface employees:				
Preparation plant men	26	26	1	53
Shopmen	14	11	8	33
Lamp men and firemen	2	2	2	6
Hoisting engineers	2	2	2	6
Supply men	2	6	-	8
Miscellaneous laborers	7	4	-	11
Foremen	2	2	1	5
Total	55	53	14	122
Supervisory employees:				
Superintendent	1	-	-	1
Clerks	3	1	1	5
Engineers	3	-	-	3
Total	7	1	1	9
Total employees	315	275	80	670

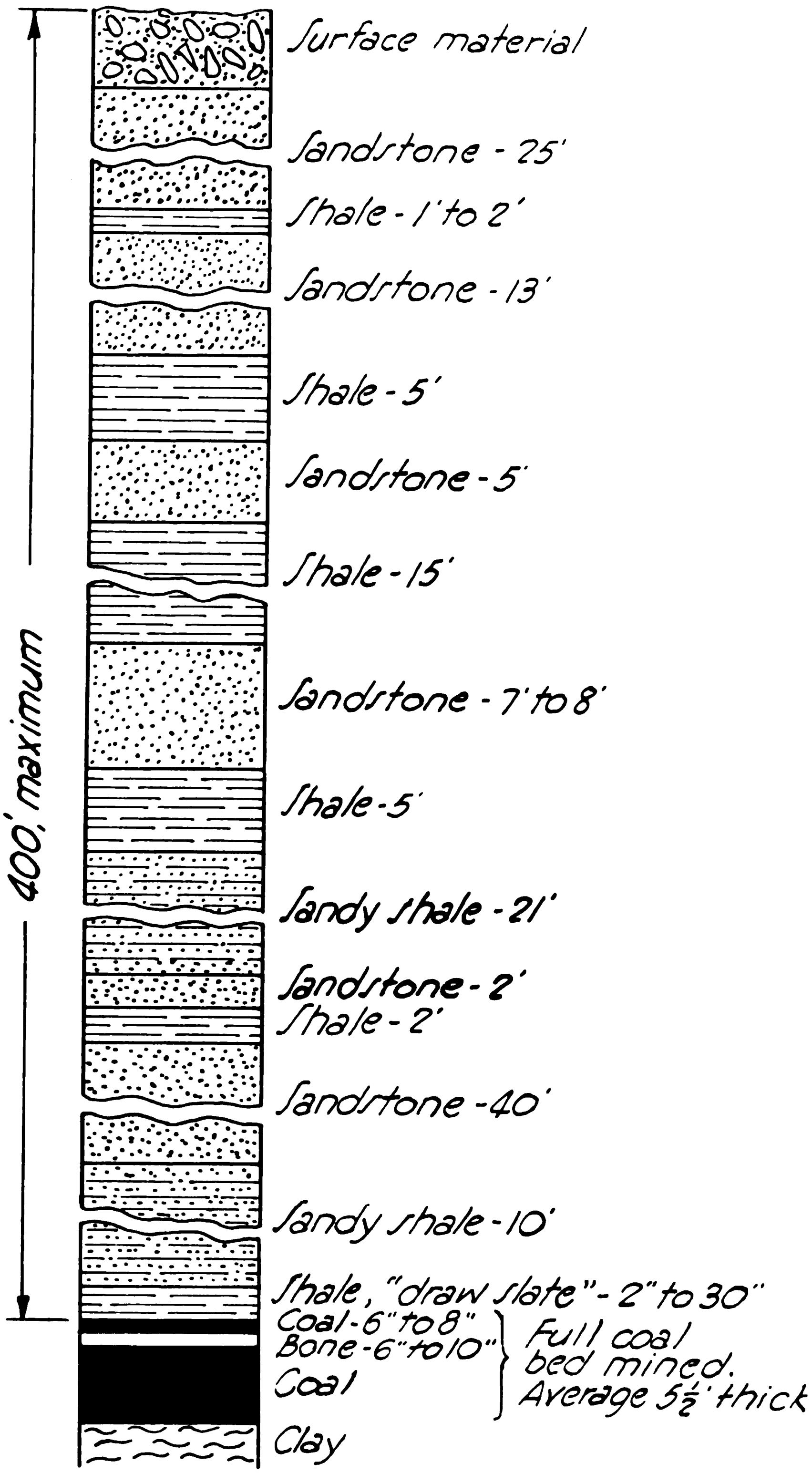


Figure 39. - Section of overburden and coal bed at mine 66.

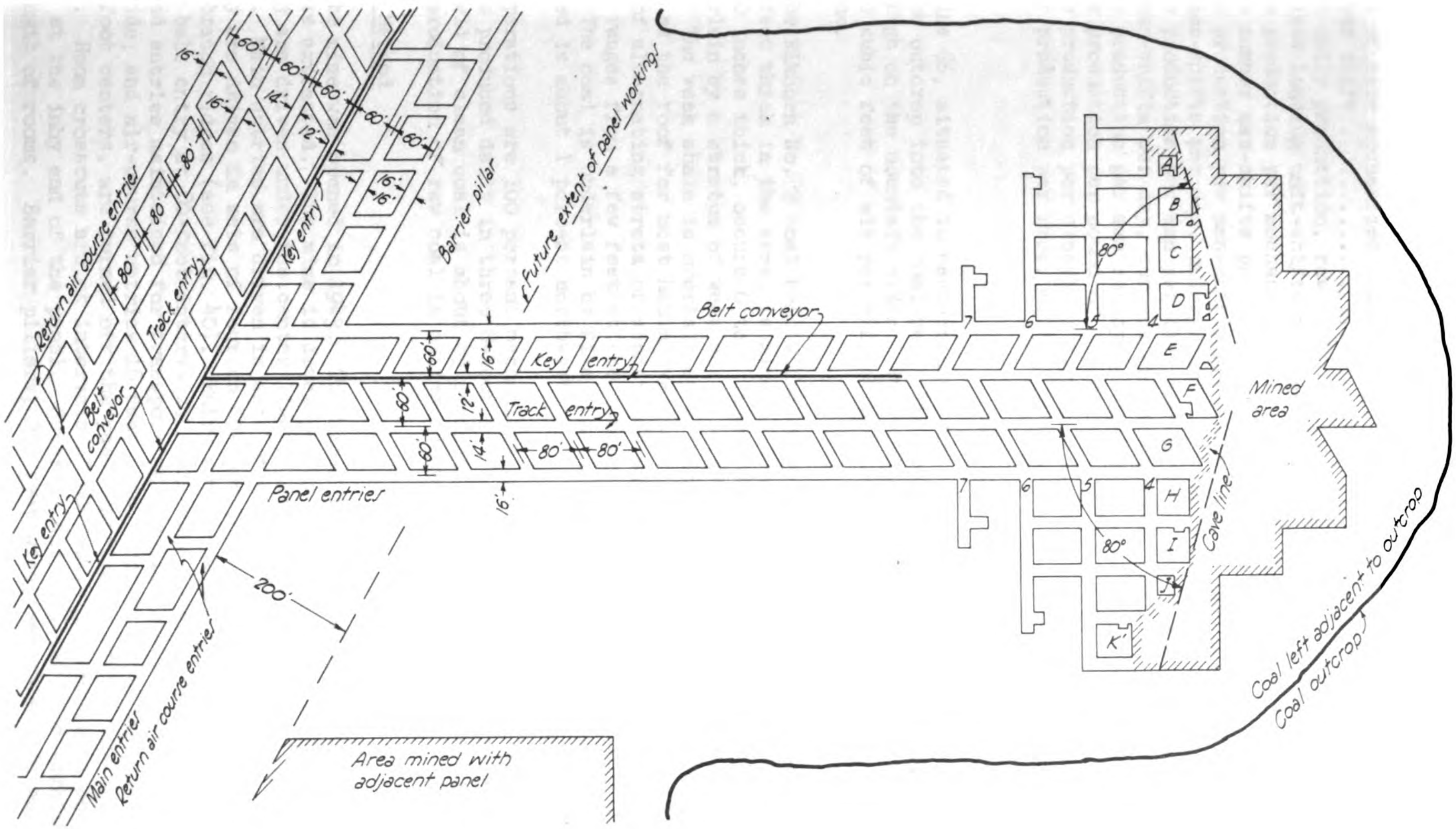


Figure 40. - Mining method at mine 66.

Summary

Percent of mine mechanized	100
Hours per shift	8
Average daily production, raw coal, tons	4,700
Mechanized loading unit-shifts per day	18
Average production per mechanized unit per shift, tons	261
Average number man-shifts per day, mechanized units	360
Average production per man-shift, mechanized units, tons	13.1
Total man-shifts per day, underground	539
Average production per man per day, underground, tons	8.7
Total man-shifts per day, surface and underground	670
Average production per man employed, tons	7.0
Average production per pound of explosive, tons	6.4
Average production per crossbar, tons	21.0
Average production per prop, tons	4.5

Mine 66

Mine 66, situated in eastern Kentucky, is opened by a number of drifts driven from the outcrop into the coal bed. The coal underlies the mountain ridges and outcrops high on the mountain sides. Two ventilating fans, operated exhausting, furnish 142,000 cubic feet of air per minute, which is circulated through eight air splits in the mine.

The Elkhorn No. 2 coal bed, which ranges from 5 to 6 feet thick, and averages 5-1/2 feet thick in the area, is mined. A parting of bone coal, which ranges from 6 to 10 inches thick, occurs 6 to 8 inches below the top of the coal bed. The coal is overlain by a stratum of weak shale, draw slate, which ranges from 2 to 30 inches thick. The weak shale is overlain by a thick stratum of sandy shale, which is maintained as the roof for most haulageways and airways. The remaining overburden consists of alternating strata of sandstones and shales. The thickness of the overburden ranges from a few feet at the outcrop to about 400 feet under the mountain tops. The coal is underlain by fire clay (see fig. 39). The regional dip of the coal bed is about 1 percent northwest.

Operations are 100 percent mechanized, and an average of 2,317 tons of clean coal is produced daily in three 8-hour shifts. Full-bed mining is practiced, and the yield of clean coal is about 85 percent of the raw coal produced. The average daily production of raw coal is estimated at 2,725 tons.

Mining Method

The mine was opened in 1943. The block system of mining is followed and pillars are extracted. The mine is developed by multiple main and panel entries, which usually are driven under the center line of ridges to the outcrop before extraction begins. Main entries are driven in sets of six on 60-foot centers. Panel entries usually are driven in sets of four on 60-foot centers and follow the center lines of short branch ridges (see fig. 40). Entry crosscuts are turned at 60 degrees off the key or belt entry at 80-foot intervals. Belt entries are driven 12 feet wide; track-equipped entries maintained for transporting supplies and man trips are driven 14 feet wide; and air-course entries 16 feet wide. Rooms, which are driven 16 feet wide on 80-foot centers, are turned off the panel entries at either 60- or 90-degree angles. Room crosscuts are at intervals of 60 feet. Extraction in rooms and pillars begins at the inby end of the panel. Outcrops and adjacent mine workings determine the length of rooms. Barrier pillars, 200 feet wide, separate main entries from outby rooms in panels. Cleats in the coal and roof rock are not pronounced and do not affect the plan of development.

At the time of this study, four mobile loading units were engaged in developing rooms and extracting room and entry pillars, and two units were engaged in entry development. One hand-loaded chain conveyor unit was being used to develop a pair of panel entries.

Each mobile loading unit generally is comprised of 11 men, 1 mobile loading machine, 1 cutting machine, 1 coal drill, 2 shuttle cars, and 1 belt conveyor. The hand-loaded chain conveyor unit comprises 5 men, 2 cutting machines, 1 coal drill, 2 chain conveyors, 1 cross conveyor, and 1 belt conveyor.

Pillar Extraction

About 44 percent of the production of the mine was from entry development and 56 percent was from pillar sections at the time of this study. About 46 percent of the coal produced from panels is from entries, rooms, and crosscuts; and 54 percent from pillars.

The size of a panel is governed by the width and length of the area of coal underlying the branch ridge. One mobile loading unit is used in each panel for both room development and pillar extraction. After panel entries have been developed, rooms are started at the inby end of the panel. Two or three rooms on each side of the entry usually are under development at a time (rooms 6 and 7, fig. 40). Room pillars and entry chain pillars are extracted in sequence as shown in figure 40, pillars A to K.

Pillars are both parallelogram and rectangular blocks 44 feet wide and 64 feet long. The pocket-and-fender system of pillar extraction is followed. Lifts are begun 11 feet wide and widened to 16 feet after the first cut (see fig. 41). At the beginning of the lift, a fender 9 feet wide is left next to the gob. The cuts then are widened, and the fender is cut through not later than the third cut. A 4-foot fender, which is left as the lift advances, is cut through on every alternate cut. The fender is drilled and blasted after the lift has been completed. Two lifts in a pillar may be working at the same time, but mining is timed so that two lifts in one pillar or final extraction of two adjacent pillars are not completed during the same shift. Coal usually is not recovered from fenders. Room pillars are mined to form a cave line about 80 degrees to the entries, and chain pillars are mined to form a pillar line perpendicular to the entries (see fig. 40).

An average mechanized unit crew follows:

Loading-machine operator	1
Loading-machine helper	1
Cutting-machine operator-driller[1]	1
Cutting-machine helper-driller[1]	1
Shot firer	1
Shuttle-car operators	2
Timberman	1
Timberman helper[2]	1
Slateman[2]	1
Foreman	1
Total	11

[1] Some units employ drillers.

[2] Not employed on all unit crews.

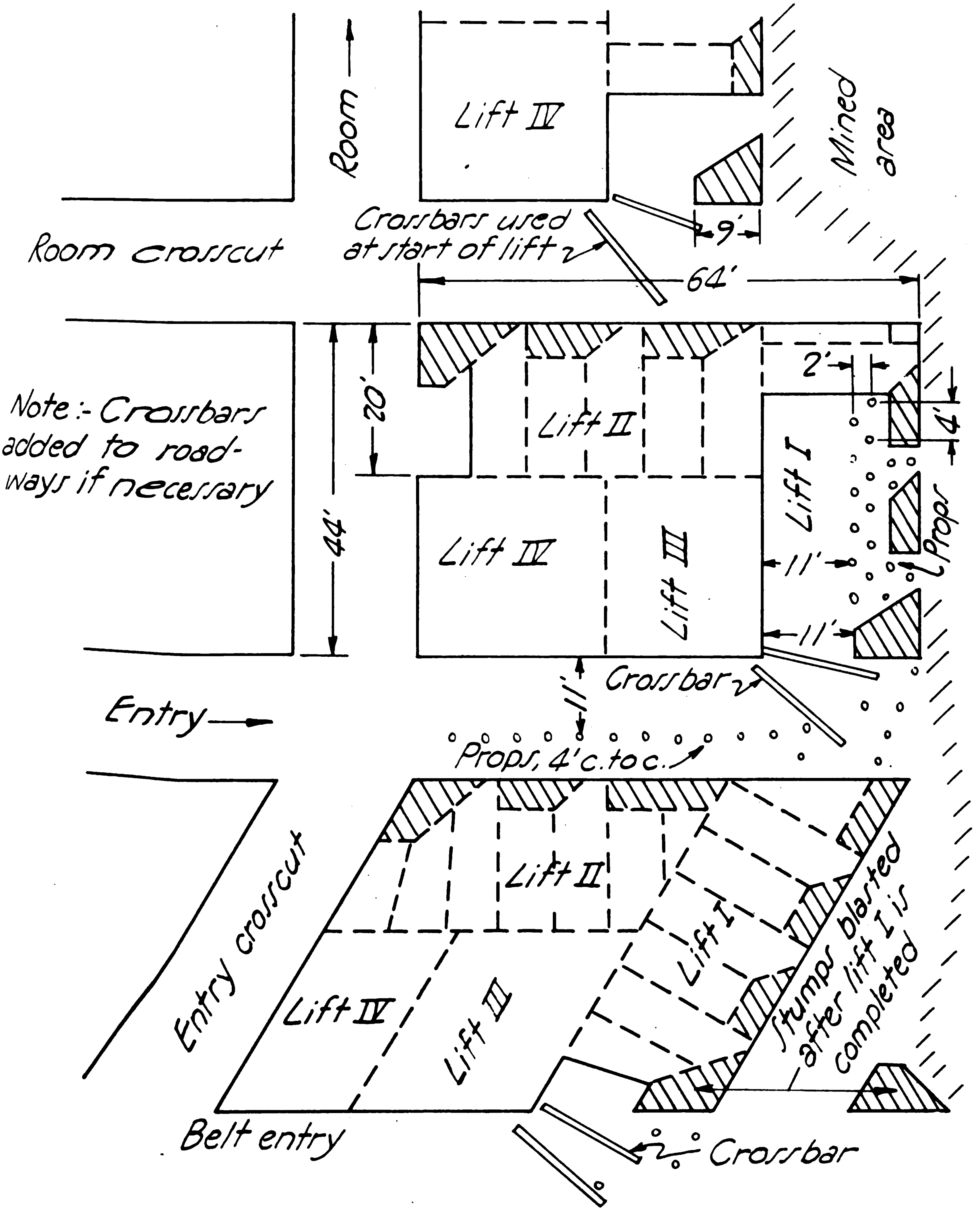


Figure 41. - Timbering details and sequence of lifts in pillars at mine 66.

The cycle of operation follows:

1. Timber.
2. Cut.
3. Drill.
4. Charge and blast.
5. Load coal.

1. Timber. - Where necessary, wood crossbars are installed on 3- to 8-foot centers in all working places as the faces are advanced. Where crossbars are not used, two rows of props are installed 4 feet apart. In pillar mining, two rows of breaker props are set across entries and crosscuts before lifts are begun. Two rows of breaker posts are set in lifts as shown in figure 41. Crossbars are used, where needed. In one section of the mine, roof bolting is being done systematically in main entry development. Bolts are installed on 4-foot centers in each direction as the entries are advanced. In this section, one crossbar is required per cut on the roadway and conveyor entry and connecting crosscuts. In other entries, a line of posts on 4-foot centers is required. In addition, four wood crossbars are placed at the intersection of entries and entry crosscuts. An average of 5.8 tons of raw coal is produced per prop and 23.1 tons per crossbar. Timbers are seldom recovered.

2. Cut. - The coal is bottom cut with shortwall cutting machines equipped with 9-foot cutter bars. Cutting machines are transported on crawler-mounted trucks.

3. Drill. - Five or seven holes are drilled per cut, depending upon the width of the coal face. In narrow places, three holes are drilled near the top and two near the middle of the coal face. In wide places, four holes are drilled near the top and three holes near the middle of the coal face. Hand-held electric auger-type drills are used.

4. Charge and blast. - Holes are charged with five cartridges of permissible explosive, which is detonated electrically in multiple blasting. Production per pound of explosive is estimated at 3.7 tons, raw coal.

5. Load coal. - Coal is loaded into shuttle cars with crawler-mounted mobile loading machines. Shuttle cars range from 3 to 6 tons capacity. Both cable-reel and battery-powered shuttle cars are used. Batteries are replaced between shifts at battery charging stations. Shuttle cars discharge the coal into hoppers at the end of panel belt conveyors. These conveyors discharge onto main-line belts, which, in turn, transport the coal to the surface. Man-trip cars and supplies are transported from the surface to the face by trolley locomotives over track installed in an entry parallel to the belt entry.

Roof Action

The stratum of soft shale, draw slate, overlying the coal generally is taken down during development work. Rock that cannot be gobbed in the mine is loaded with the coal and sent to the cleaning plant. The draw slate usually is supported in the lifts in pillar mining and in the entries where roof bolts are used. The bone parting and the coal above it (fig. 39) are supported in the pair of entries being developed by conveyor mining.

In pillar mining, the roof caves by falling in broad, thick slabs instead of shearing vertically at the fenders and breaker posts. Caves are high and follow pillar mining closely. Cracks are known to penetrate the entire overburden and large quantities of surface water enter the mine in caved areas during wet weather. Little water is encountered in development work.

4648

Recovery

Because of the water hazard, bad roof, and the weathered condition of the coal near outcrops, a barrier of 50 feet or more, depending on surface contours, is left between the outcrop and mine workings. Barrier pillars adjacent to main entries and main-entry chain pillars are extracted during retreat from mined-out sections of the mine. Under the system of mining used, company officials estimate that panel recovery and over-all mine recovery is about the same, and they range from 80 to 85 percent, exclusive of the coal left along the outcrop.

Classification of Employees

Classification	Shift			Total
	1st	2d	3d	
Mechanized units:				
Loading-machine operators	6	6	6	18
Loading-machine helpers	6	6	6	18
Cutting-machine operators	6	6	6	18
Cutting-machine helpers	6	6	6	18
Drillers	4	4	4	12
Shuttle-car operators	12	12	12	36
Timbermen	6	6	6	18
Timbermen helpers	4	4	4	12
Slatemen	4	4	4	12
Chain conveyor men	5	5	5	15
Shot firers	6	6	6	18
Foremen	6	6	6	18
Total	71	71	71	213
Other underground employees:				
Conveyor unloading operators	18	18	18	54
Motormen	2	2	2	6
Brakemen	2	2	2	6
Brattice men	1	1	1	3
Wiremen	1	1	1	3
Rock drillers and helpers	2	2	2	6
Rock duster	1	-	-	1
Battery station attendants	1	1	-	2
Belt mechanics	2	2	2	6
Mechanics	3	2	2	7
General underground laborers	2	2	2	6
Mine foremen	2	1	1	4
Total	37	34	33	104
Total underground employees	108	105	104	317
Surface employees:				
Hoisting engineers	1	1	1	3
Carpenters	2	-	-	2
Repairmen	3	1	1	5
Blacksmiths	1	1	-	2
Truck drivers	2	-	-	2
Bath-house attendant	1	-	-	1
Bulldozer operators	1	1	-	2
Lamp men	1	1	1	3
Greasers	-	1	1	2
Boom men (belt men)	1	1	1	3

Classification	Shift 1st	Shift 2d	Shift 3d	Total
Surface employees (Cont.):				
Laborers	7	-	-	7
Special repairman (tipple)	1	-	-	1
Repairmen (tipple)	2	2	2	6
Cone operators	1	1	1	3
Greasers (tipple)	1	1	1	3
Laborers (tipple)	1	1	1	3
Slate pickers	2	2	2	6
Sampler	1	-	-	1
Railroad-car loaders and droppers	2	2	2	6
Slate hoistmen	1	1	1	3
Tipple engineer and outside foreman	1	-	-	1
Chief electrician	1	-	-	1
Repair foremen	-	1	1	2
Total	34	18	16	68
Supervisory employees:				
Superintendent	1	-	-	1
Office clerks	4	-	-	4
Supply clerk	1	-	-	1
Engineers	2	-	-	2
Property engineer	1	-	-	1
Total	9	-	-	9
Total employees	151	123	120	394

Summary

Percent of mine mechanized	100
Hours per shift	8
Average yield, clean coal from raw coal, percent	85
Mechanized units, mobile loading	6
Mechanized unit-shifts per day, mobile loading	18
Mechanized units, hand loading onto conveyors	1
Mechanized unit-shifts per day, hand loading onto conveyors	3
Average number man-shifts per day, mobile loaders	198
Average number man-shifts per day, conveyors	15
Total man-shifts per day, mechanized units	213
Total man-shifts per day, underground	317
Total man-shifts per day, surface and underground	394
Over-all recovery, percent	80-85

	Raw coal[1]	Clean coal
Average daily production, mine, tons	2,725	2,317
Average daily production, mobile loading units, tons	2,590	2,182
Average daily production, conveyor unit, tons	[2]135	135
Average production per mobile loading unit, per shift, tons	143.9	121.2
Average production per conveyor unit, per shift, tons	[2]45.0	45.0
Average production per man-shift, mobile loading, tons	13.1	11.0
Average production per man-shift, conveyors, tons	9.0	9.0
Average production per man-shift, mechanized units, tons	12.8	10.9
Average production per man per day, underground, tons	8.6	7.3
Average production per man employed, tons	6.9	5.9
Average production per pound of explosive, tons	3.7	3.1
Average production per prop, tons	5.8	4.9
Average production per crossbar, tons	23.1	19.6

[1] Raw coal includes all material sent to tipple.

[2] Raw coal does not include bone or roof rock.

Mine 67

Mine 67, situated in eastern Kentucky, is opened by three drifts driven from the outcrop into the coal bed. One ventilating fan, operated exhausting, furnishes 110,000 cubic feet of air, which is circulated through eight air splits in the mine.

The Taggart coal bed, which ranges from 51 to 80 inches thick and averages 62 inches thick in the area, is mined (see fig. 42). No partings occur in the coal bed in present mine workings. The coal is overlain by a stratum of weak shale, draw slate, that ranges from 2 to 8 feet thick. The draw slate is overlain by sandy shale that grades to sandstone about 2 feet above the draw slate. The remaining overburden comprises strata of thick sandstones, shales, and one coal bed about 4 feet thick, which occurs approximately 60 feet above the Taggart bed. The thickness of the overburden ranges from a few feet at the outcrop to about 1,000 feet under the mountain tops. The coal is underlain by hard clay. The regional dip of the coal bed is about 2 percent southwest, but rolls that result in grades up to 15 percent occur locally.

Operations are 100 percent mechanized, and an average of 2,650 tons of raw coal are produced daily in two 8-hour shifts.

Mining Method

The mine was opened during World War I and closed after 8 years of operation. In 1947, it was reopened and operations were mechanized. The room-and-pillar system of mining is followed and pillars are extracted. Main entries are driven in sets of three to six on 60-foot centers (see fig. 43). Panel entries, butt entries, are turned at 90 degrees to the right and left off main entries and are driven on 50-foot centers parallel to the face cleats in the coal bed. Where rooms are to be mined off both sides of panel entries, double panels, three entries are driven; where rooms are to be driven off one side, single panels, two entries usually are driven. All entries are 16 feet wide. Panel entries are driven 1,630 feet before room development and pillar extraction begin. Rooms are turned at 90 degrees to the panel entries and driven 36 feet wide on 72-foot centers to a depth of 200 or 250 feet. Rooms are driven perpendicular to the face cleats in the coal.

At the time of this study, all active mining was in the Taggart coal bed. However, mining had been conducted in a bed about 40 feet below the Taggart bed. Main entries in the upper bed are directly over the entries in the lower bed, and the entry chain pillars are columnized. The two levels are connected by raises at intersections of panel entries and main entries, and main haulage is in the lower bed.

An average of 24 shaking conveyor units are in operation each shift. Three entry development units employ shaking conveyors equipped with self-loading heads. The production of these units per man per shift averages about 25 percent more than the hand-loaded conveyor units in room-and-pillar mining.

Each conveyor unit comprises four to seven men, one cutting machine, one coal drill, one room or entry conveyor, and one face conveyor in room-and-pillar mining. Two or three conveyor units are used in the development of a set of panel entries, five units in retreating single panels, and seven units in retreating double panels. Each panel is equipped with a 30-inch belt conveyor.

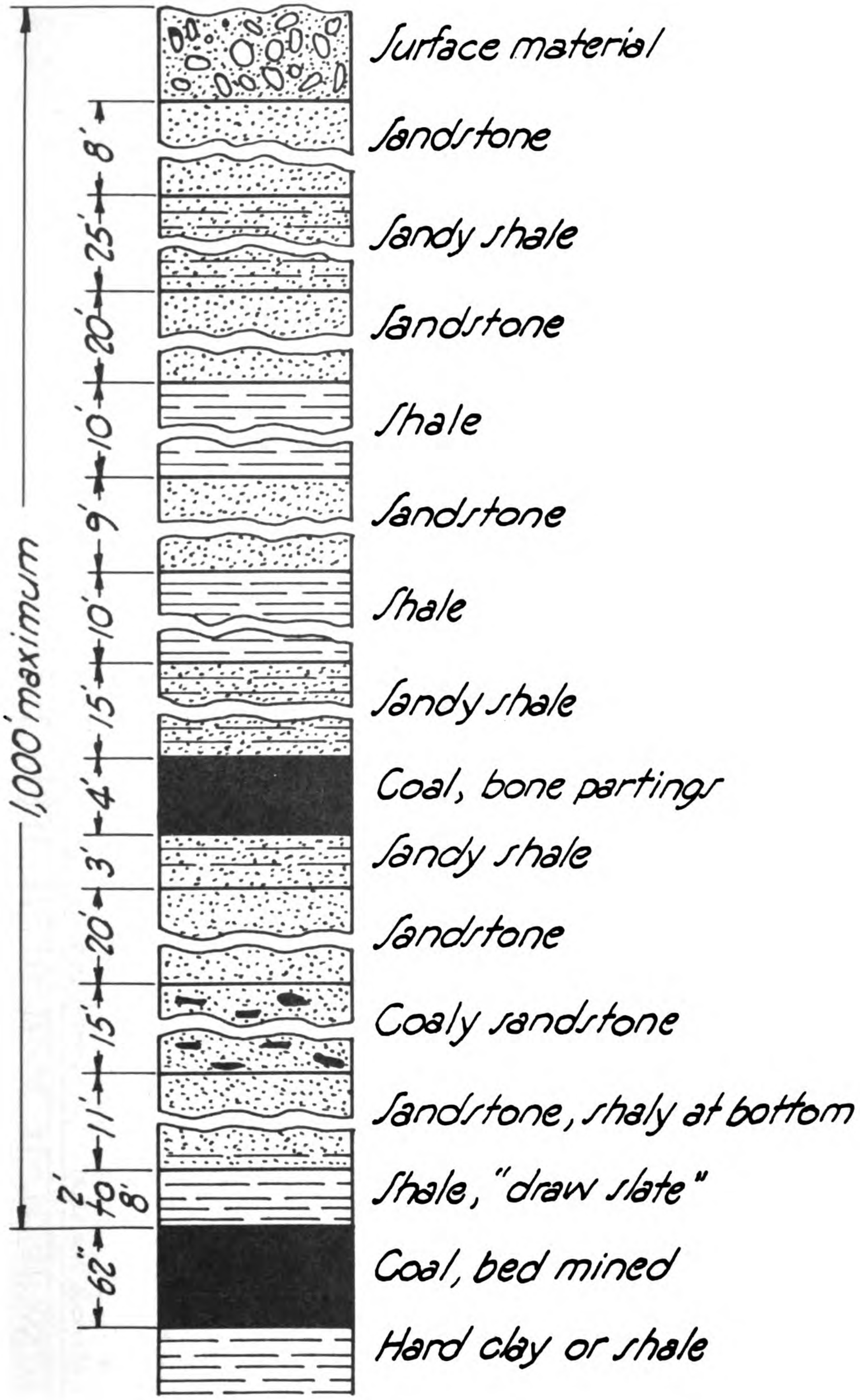


Figure 42. - Section of coal bed and overburden at mine 67.

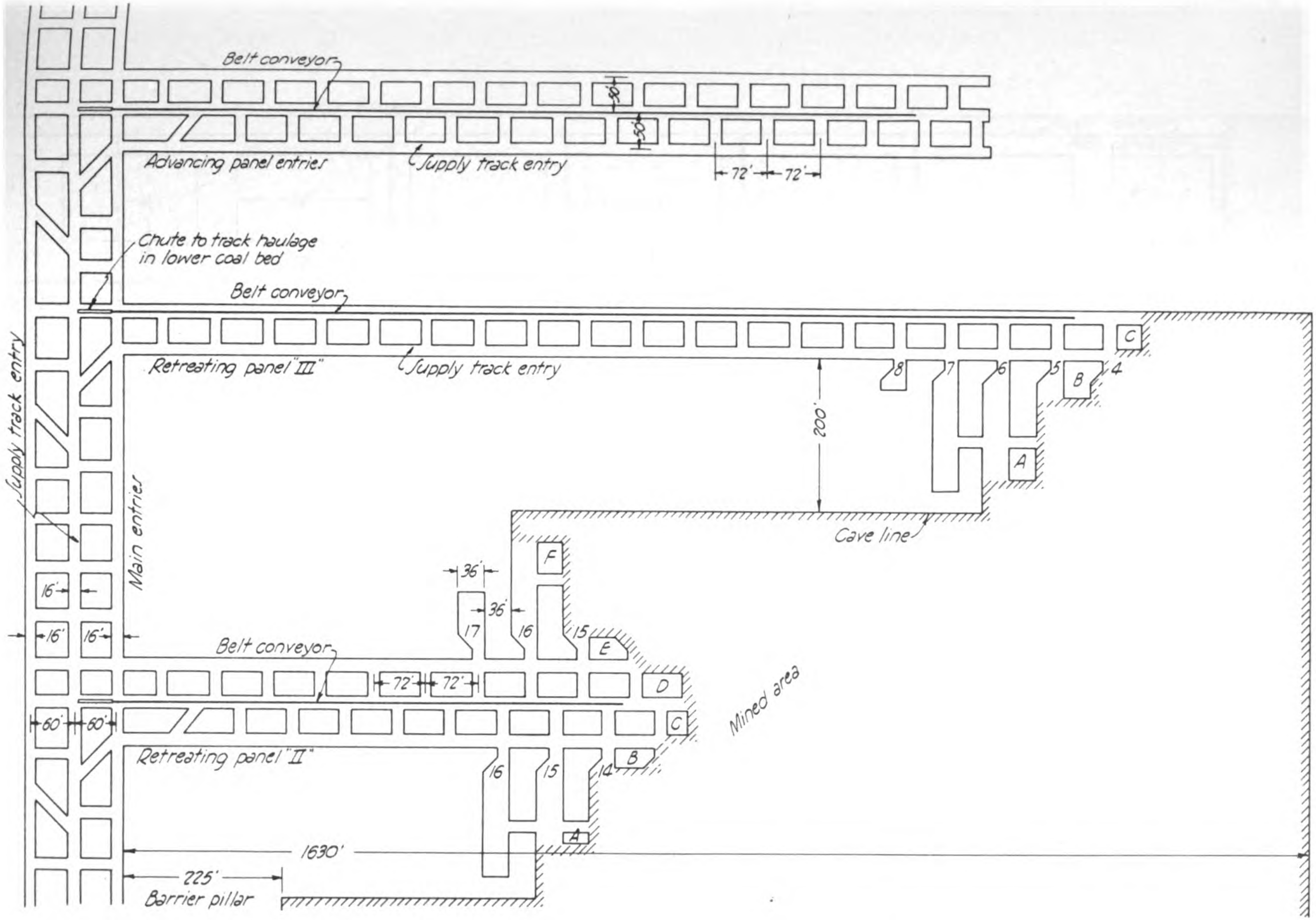


Figure 43. - Mining method at mine 67.

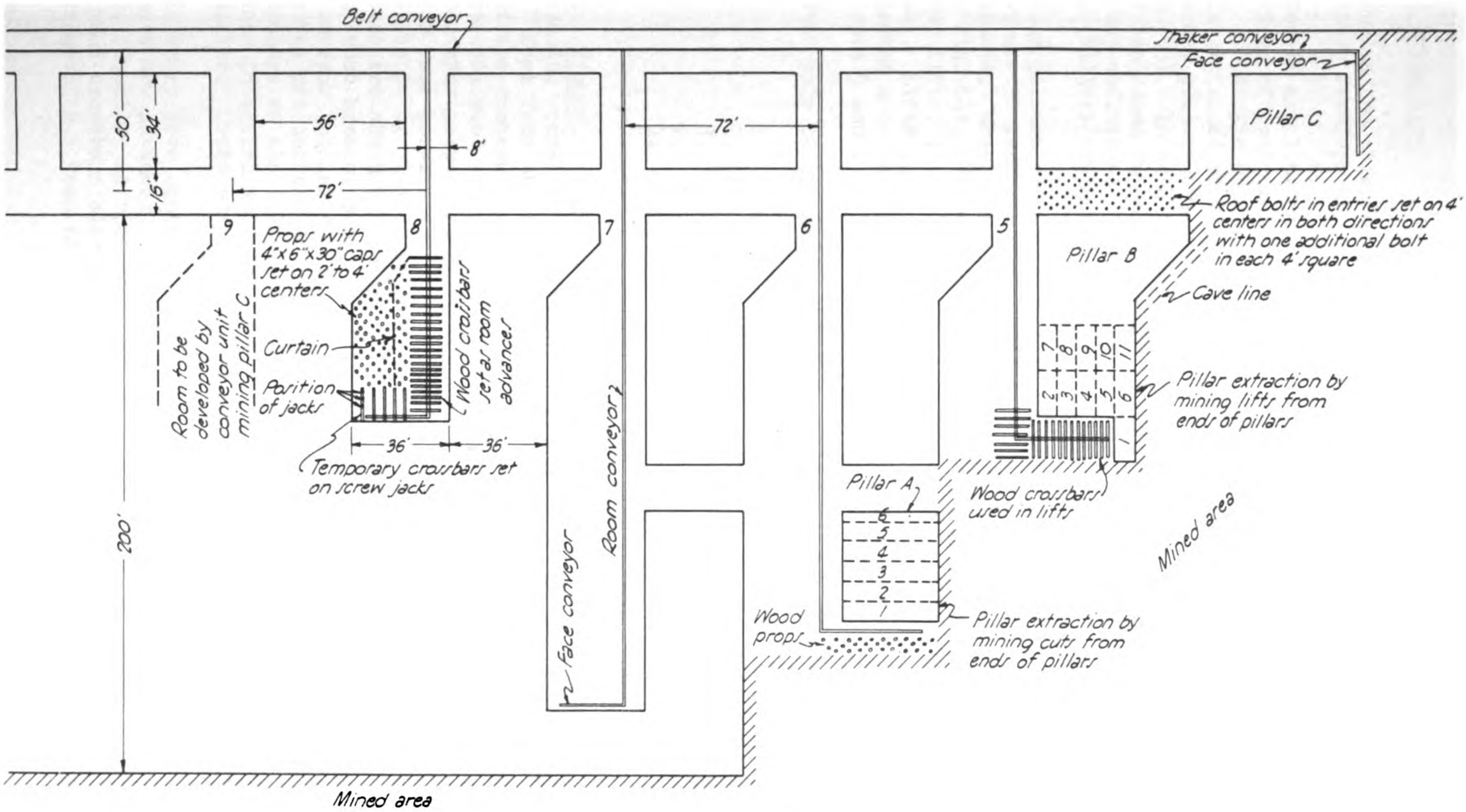

Belt conveyor
Shaker conveyor
Face conveyor
Pillar C
50'
34'
16'
56'
8'
72'
72'
9
8
7
6
5
Props with 4"x6"x30" caps set on 2' to 4' centers
Curtain
Position of jacks
Wood crossbars set as room advances
Room to be developed by conveyor unit mining pillar C
36'
36'
Temporary crossbars set on screw jacks
200'
Face conveyor
Room conveyor
Roof bolts in entries set on 4' centers in both directions with one additional bolt in each 4' square
Pillar B
Cave line
7 8 9 10 11
2 3 4 5 6
1
Pillar extraction by mining lifts from ends of pillars
Wood crossbars used in lifts
Pillar A
6 5 4 3 2 1
Wood props
Pillar extraction by mining cuts from ends of pillars
Mined area
Mined area

Figure 44. - Pillar extraction at mine 67.

Pillar Extraction

During the calendar year preceding this study, 20 percent of the production was from entry development, 32 percent from room development, and 48 percent from pillars.

Panels are 1,630 feet long and range from 270 to 630 feet wide. Twenty rooms are driven off one or both sides of panel entries, beginning at the inby end of the panel. In single panels, two rooms usually are under development, one about half a room length ahead of the other (rooms 7 and 8 single panel III, fig. 43). At the same time, pillars are extracted by three units inby these rooms (pillars A, B, and C, fig. 43). In double panels, three units operate on each side of the panel, and one or two rooms on each side are under development at a time (see panel II, fig. 43). One additional conveyor unit is used to extract the chain pillars in a double panel. Pillars are mined in sequence as shown alphabetically in figure 43.

Room pillars are 36 feet wide and range from 50 to 90 feet long. Entry chain pillars are 34 feet wide and 56 feet long. The open-end system of pillar extraction is followed. Where conditions permit, cuts are taken off the ends of pillars (pillar A, fig. 44). Where roof conditions are bad or where roof falls are against the pillars, lifts, 16 to 20 feet wide, are mined from the ends of pillars (pillar B, fig. 44). Lifts comprise about five cuts. The last 5 to 10 feet in some pillars are blasted and loaded without cutting because this coal is often crushed by heavy roof (cuts 5 and 6, pillar A, fig. 44).

The cycle of operations follows:

1. Timber.
2. Cut.
3. Drill.
4. Extend and move conveyors and extend curtain.
5. Charge and blast.
6. Load coal.

1. Timber. - Timbers are advanced to the face as the coal is loaded from a cut. In advancing rooms, wood crossbars are installed over the room conveyor, which is about 8 feet from the inby side of the room (room 8, fig. 44). The area on the outby side of the conveyor is timbered at the face by a system of fore-poling as the face is advanced; wood crossbars 14 feet long are installed on 4-foot centers over the face conveyor perpendicular to the face; these crossbars, which are supported by three or four screw jacks, are moved forward as the face is advanced. Wood props with 4- by 6- by 30-inch wood cap pieces are set on 2- to 4-foot centers as the crossbars are advanced. Where cuts are taken from the ends of pillars in pillar mining, wood breaker props are set on 1- to 3-foot centers on the gob side of the face conveyor (pillar A, fig. 44). Where conditions require that pillars be mined with lifts off the end of a pillar, three-piece timber sets are placed on 1- to 4-foot centers as the lift is advanced (pillar B, fig. 44). Temporary wood cribs are sometimes installed in room crosscuts to keep them open until mining is begun in the inby pillar. Cribs are the only timbers recovered.

In entry development, the roof is bolted on 4-foot centers in each direction as the faces are advanced. Another bolt is then installed in the middle of each 4-foot square. Usually, 11 roof bolts are used per cut in an entry 16 feet wide. In addition, wood crossbars also are set on 4- to 6-foot centers as the entries are advanced. An average of 2.4 tons of coal are produced per prop and 9.5 tons per crossbar.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

2. Cut. - As soon as the right corner of a fall of coal is loaded, cutting begins and proceeds across the face as the coal is loaded. The coal is bottom cut with shortwall cutting machines equipped with 8-foot cutter bars. One cutting machine is used per conveyor unit.

3. Drill. - The coal is drilled with hand-held electric auger-type drills. In rooms, nine holes usually are drilled per cut; four near the top and five near the middle of the coal face. About six holes are drilled per cut in entries, three near the top and three near the middle of the coal face. Drilling is begun before the machine cut is completed.

4. Extend and move conveyors and extend curtain. - When the cut is completed, the cutting machine is moved away from the face, and the room conveyor is extended in advancing rooms and shortened in pillar mining. The face conveyor is moved as a unit to the face. The curtain line, supported by props, is then extended along the center line of the room to the face conveyor.

5. Charge and blast. - Holes are charged with 3-1/2 to 4 cartridges of permissible explosive, which is detonated electrically. Conveyors are operated when the coal is blasted because some coal falls onto the face conveyor after the blast. In room work, charges are fired one at a time to prevent overloading the conveyor. In entry work where face conveyors are not used, two to six charges are fired at a time. Production per pound of explosive is estimated at 3.2 tons.

6. Load coal. - Coal is hand-loaded onto shaking conveyors in room-and-pillar mining and loaded with shaking conveyors equipped with self-loading heads in entry mining. Room conveyors discharge the coal onto 30-inch belt conveyors in the panel entries. These conveyors transport the coal to the main entries and discharge it into steel chutes installed in the raises connecting the two levels. Mine cars of 7.5-ton capacity are loaded at the chutes on the lower level. Trips of mine cars are spotted at the chutes and transported to the surface by trolley locomotives. Man-trip cars and supplies are transported from the surface to the face by trolley locomotives over track installed in the main entry in the upper level and in one entry parallel to the belt entry in each panel.

Roof Action

The stratum of weak shale, draw slate, overlying the coal bed must be supported during mining. In pillar mining, this roof rock usually breaks freely, and close timbering is required to prevent premature roof falls. The shale falls in broad slabs along the cave line and follows pillar mining closely except in the chain pillar areas where the roof in entries has been bolted. The sandy shale and sandstone strata overlying the immediate shale roof usually bend before breaking, and this concentrated weight crushes the coal in the last 5 or 10 feet in room pillars and in chain pillars. However, squeezes and bottom heaving seldom occur. Apparently, there is no difference in roof action under small or great thicknesses of overburden at this mine.

Recovery

Because subjacent mining planned for columnized main entry pillars, may be conducted in the near future, main entry chain and barrier pillars will not be extracted until final retreat mining begins. For this reason, over-all mine recovery has not been estimated. Recovery in panels is estimated by company officials at 97 percent under average favorable conditions, excluding barrier pillars and coal left unmined along outcrops.

TABLE 1. - Summary of performance of mobile loading units and conveyor units

		Mine					
		56	57	58	59	60	61
1.	Description of mechanization:						
	A. Cutting machines	Shortwall	Shortwall	Universal, ribber-tired	Universal, track-mounted	Shortwall	Shortwall
	B. Mobile loading units:						
	a. Loading machines	Crawler-mounted	Crawler-mounted	Crawler-mounted	Track-mounted	Track-mounted and rubber-tired	Crawler-mounted
	b. Machines load into	Shuttle cars	Chain conveyors	Shuttle cars	Mine cars	Mine cars and shuttle cars	Chain conveyors
	C. Conveyor units:						
	a. Conveyors, type	Chain conveyor	Chain conveyor	-	-	Shaking conveyors	Chain conveyors
	b. Conveyors load into	Mine cars	Mine cars	-	-	Mine cars	Belt conveyors
2.	Location of mine	Pennsylvania	Pennsylvania	Pennsylvania	Pennsylvania	Kentucky	West Virginia
3.	Mechanization of mine ... percent	100	100	100	100	78	100
4.	Thickness and dip of bed	39 inches - flat	32 inches - flat	54 inches - flat	84 inches - flat	45 inches - flat	38 inches - flat
5.	Number and hours of shift, underground	3 - 8-hour	2 - 8-hour	2 - 8-hour	4 - 8-hour	3 - 8-hour	2 - 8-hour
6.	Number and hours of shift, surface	2 - 8-hour	2 - 8-hour	1 - 8-hour	3 - 8-hour	2 - 8-hour	1 - 8-hour
7.	Average daily production mine ... tons	3,000	600	2,017	8,300	6,100	2,283
8.	Mobile loading units:						
	A. Number units	9	3	4	8	14	2
	B. Unit shifts per day	20	6	8	32	33	4
	C. Average production per unit per shift ... tons	137	90	252	260	125	120
	D. Average number men per unit per shift	9.5	7	11	15	13	17
	E. Man-shifts per day	188	44	88	480	431	34
	F. Average daily production ... tons	2,730	540	2,017	8,300	4,125	478
	G. Average production per man per shift ... tons	14.0	12.3	22.9	17.3	9.6	14.1
9.	Conveyor units:						
	A. Number units	3	1	-	-	9	23
	B. Unit-shifts per day	6	2	-	-	18	46
	C. Average production per unit per shift ... tons	45	[1]30	-	-	37	39
	D. Average number men per unit per shift	4	6	-	-	5	4
	E. Man-shifts per day	26	12	-	-	94	192
	F. Average daily production ... tons	270	60	-	-	660	1,805
	G. Average production per man per shift ... tons	10.4	5.0	-	-	7.0	9.4
10.	Total number of employees, underground	324	70	133	728	969	318
11.	Average production per man per shift, underground...tons	9.3	8.6	15.2	11.4	6.3	7.2
12.	Total number of employees, surface and underground	405	82	156	839	1,105	390
13.	Average production per shift per man employed ... tons	7.4	7.3	12.9	9.9	5.5	5.9
14.	Average production per pound of explosive ... do.	4.25	11.0	5.0	4.0	6.25	8.7
15.	Average production per prop ... do.	-	-	-	-	1.5	3.8
16.	Average production per crossbar ... do.	-	-	-	19.5	37.8	-
17.	Average production per roof bolt ... do.	-	-	-	-	-	-
18.	Estimated recovery, panels ... percent	85	85	84	88	-	-
19.	Estimated recovery, mine ... do.	75	-	75	80	87	-

		Mine					
		62	63	64	65	66	67
1.	Description of mechanization:						
	A. Cutting machines	Arcwall, track-mounted	Arcwall, crawler-mounted	Universal, rubber-tired	Arcwall, track-mounted	Shortwall	Shortwall
	B. Mobile loading units:						
	a. Loading machines	Track-mounted	Crawler-mounted	Crawler-mounted	Track-mounted	Crawler-mounted	-
	b. Machines load into	Mine cars	Shuttle cars	Shuttle cars	Mine cars	Shuttle cars	-
	C. Conveyor units:						
	a. Conveyors, type	-	-	-	-	-	Shaking conveyors
	b. Conveyors load into	-	-	-	-	-	Belt conveyors
2.	Location of mine	West Virginia	West Virginia	West Virginia	West Virginia	Kentucky	Kentucky
3.	Mechanization of mine ... percent	100	100	100	100	100	100
4.	Thickness and dip of bed	6 to 12 feet - flat	45 inches - flat	84 inches - flat	84 inches - flat	72 inches - flat	62 inches - flat
5.	Number and hours of shift, underground	3 - 8-hour	3 - 8-hour	2 - 8-hour	2 - 8-hour	3 - 8-hour	2 - 8-hour
6.	Number and hours of shift, surface	2 - 8-hour	2 - 8-hour	2 - 8-hour	2 - 8-hour	3 - 8-hour	2 - 8-hour
7.	Average daily production mine ... tons	2,700	4,471	1,000	4,700	2,725	2,650
8.	Mobile loading units:						
	A. Number units	6	10	1	9	6	-
	B. Unit-shifts per day	13	21	2	18	18	-
	C. Average production per unit per shift ... tons	207.7	213	500	261	143.9	-
	D. Average number men per unit per shift	13	12	15	20	11	-
	E. Man-shifts per day	165	252	30	360	198	-
	F. Average daily production ... tons	2,700	4,471	1,000	4,700	2,590	-
	G. Average production per man per shift ... tons	16.4	17.7	33.3	13.1	13.1	-
9.	Conveyor units:						
	A. Number units	-	-	-	-	1	24
	B. Unit-shifts per day	-	-	-	-	3	48
	C. Average production per unit per shift ... tons	-	-	-	-	45	55.2
	D. Average number men per unit per shift	-	-	-	-	5	7
	E. Man-shifts per day	-	-	-	-	15	358
	F. Average daily production ... tons	-	-	-	-	135	2,650
	G. Average production per man per shift ... tons	-	-	-	-	9.0	7.4
10.	Total number of employees, underground	235	365	47.5	539	317	494
11.	Average production per man per shift, underground...tons	11.5	12.2	21.1	8.7	8.6	5.4
12.	Total number of employees, surface and underground	302	463	63	670	398	533
13.	Average production per shift per man employed ... tons	8.9	9.7	15.9	7.0	6.8	5.0
14.	Average production per pound of explosive ... do.	2.5	6.6	4.0	6.4	3.7	3.2
15.	Average production per prop ... do.	12.5	12.7	-	4.5	5.8	2.4
16.	Average production per crossbar ... do.	25.0	-	-	21.0	23.1	9.5
17.	Average production per roof bolt ... do.	-	-	4.5	-	-	-
18.	Estimated recovery, panels ... percent	-	80	-	-	80-85	-
19.	Estimated recovery, mine ... do.	-	70	-	-	80-85	-

[1] Crews also brush and load rock in track haulage entry.

Classification of Employees

Classification	Shift 1st	2d	3d	Total
Mechanized units:				
Conveyor men (including cutting machine men)	128	140	-	268
Timbermen	25	10	-	35
Foremen (units)	15	7	-	22
Maintenance men	13	11	4	28
Maintenance foremen	2	1	2	5
Total	183	169	6	358
Other underground employees:				
Motormen	6	6	10	22
Brakemen	7	5	10	22
Supplies crew	-	-	22	22
Timbermen and helpers	5	-	2	7
Trackmen	3	-	-	3
Ventilation men	6	-	-	6
Drainage men	2	-	-	2
Rock drillers	8	12	-	20
Beltmen	10	13	-	23
Installation man	1	-	-	1
Examiners	-	-	5	5
Maintenance foremen	1	1	-	2
Mine foreman	1	-	-	1
Total	50	37	49	136
Total underground employees	233	206	55	494
Surface employees:				
Tipple crew	13	-	-	13
Shop men	3	3	3	9
Supply man	1	-	-	1
Lamp men	2	1	1	4
Tipple foreman	1	-	-	1
Total	20	4	4	28
Supervisory employees:				
General superintendent	1	-	-	1
Mine manager	1	-	-	1
Engineers	5	-	-	5
Safety engineer	1	-	-	1
Office clerks	1	1	1	3
Total	9	1	1	11
Total employees	262	211	60	533

Summary

Percent of mine mechanized	100
Hours per shift	8
Average daily production, mine, tons	2,650
Conveyor unit-shifts per day	48
Average number man-shifts per day, conveyor units	358
Average production per conveyor unit per shift, tons	55.2
Average production per man-shift, conveyor units, tons	7.4
Man-shifts per day, underground	494
Average production per man per day, underground, tons	5.4
Total man-shifts per day, surface and underground	533
Average production per man employed per day, tons	5.0
Average production per prop, tons	2.4
Average production per crossbar, tons	9.5
Average production per pound of explosive, tons	3.2